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E.522

TELEPHONE NETWORK AND ISDN

QUALITY OF SERVICE, NETWORK MANAGEMENT AND TRAFFIC ENGINEERING

NUMBER OF CIRCUITS IN A HIGH-USAGE GROUP

ITU-T Recommendation E.522

(Extract from the *Blue Book*)

NOTES

1 ITU-T Recommendation E.522 was published in Fascicle II.3 of the *Blue Book*. This file is an extract from the *Blue Book*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Recommendation E.522

NUMBER OF CIRCUITS IN A HIGH-USAGE GROUP

1 Introduction

For the economic planning of an alternate routing network the number of circuits in a high-usage group should be determined so that the annual charges for the whole network arrangement are at a minimum. This is done under the constraint that given requirements for the grade of service are fulfilled. In the optimum arrangement, the cost per erlang of carrying a marginal amount of traffic over the high-usage route or over the alternative route is the same.

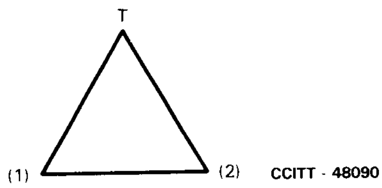

FIGURE 1/E.522

The optimum number of high-usage circuits, *n*, from one exchange (1) to another exchange (2) is therefore obtained from the following expression when the overflow traffic is routed over a transit exchange T (route 1-T-2, see Figure l/E.522).

$$F_n(A) = A\left\{E_{1,\,n}(A) - E_{1,\,(n+1)}(A)\right\} = M \times \frac{\text{annual charge (1 - 2)}}{\text{annual charge (1 - T - 2)}}$$

A is the traffic flow offered, for the relation “1-2”, in the Erlang loss formula for a full availability group. The expression $F_n(A)$ gives the marginal occupancy[1)] (improvement function) for the high-usage group, if one more circuit were added.

M is the *marginal utilization factor*[2)] *for the final route* “1-T-2” (which has nothing to do with cost ratio), if one additional circuit were provided. The annual charges are marginal charges for adding one additional circuit to route “1-2” and likewise to route “1-T-2”.

Planning of an alternate routing network is described in the technical literature (see [1] to [10]).

Annual charge as used in this Recommendation refers to investment costs.

2 Recommended practical method

2.1 *Field of application*

It must be recognized that the conditions applying to alternative routing will vary widely between the continental network and the intercontinental network. Significant differences between the two cases apply to the length and cost of circuits, the traffic flow and the different times at which the busy hours occur. The method described attempts to take account of these factors in so far as it is practicable to do so in any simplified procedure.

[1)] Marginal occupancy is often called LTC (last trunk capacity).

[2)] Marginal utilization is often called ATC (additional trunk capacity).

2.2 *Traffic statistics*

The importance of reliable traffic estimates should be emphasized. Traffic estimates are required for each of the relations in question, for both the busy hour of the relation and for the busy hour of each link of the routes to which the traffic overflows. Since this may be affected by the high-usage arrangements finally adopted, it will be necessary to have traffic estimates for each relation covering most of the significant hours of the day. This applies particularly to the intercontinental network where the final routes carry traffic components with widely differing busy hours.

2.3 *Basis of the recommended method*

The method is based on a simplification of the economic dimensioning equations described under 1. Introduction. The simplifying assumptions are:

i) the ratios of the alternative high-usage annual charges are grouped in classes and a single ratio selected as representative for each class. This is acceptable because total network costs are known to be relatively insensitive to changes in the annual charges ratio;

ii) the marginal utilization factor M applicable to the overflow routes is regarded as constant within a range of circuit group sizes;

Size of group (number of circuits)	Value of M
For less than 10	0.6
For 10 or more	0.8

iii) each high-usage group will be dimensioned against the cheapest alternative route to which traffic overflows. (That is, the effect of parallel alternative routes is ignored.)

Where greater precision is required in either network or individual route dimensioning, more sophisticated methods may be employed (see [5] and [7].

2.4 *Determination of cost ratio*

In continental and intercontinental working, the number of circuits to be provided in high-usage circuit groups depends upon the ratio of the annual charges estimated by the Administrations involved. The annual charge ratio (see Table 1/E.522) is defined as:

$$R = \frac{\text{annual charge of one additional circuit on the alternative route}}{\text{annual charge of one additional circuit on the high-usage route}}$$

The "annual charge of one additional circuit on the alternative route" is calculated by summing:

– the annual charge per circuit of each link comprising the alternative route, and

– the annual charge of switching one circuit at each intermediate switching centre.

When a third Administration is involved, it may be necessary to calculate the annual charge for switching at the intermediate centre from the transit switching charge per holding minute[3)]. This may be done as follows:

Annual charges for switching = $M \times 60 \times F \times 26 \times 12 \times$ transit switching charge per holding minute.

In the calculation of the conversion factor F from busy hour to day, its dependence on the traffic offered to the high usage route, the overflow probability and the time difference should be taken into account. As a guideline, Table 1/E.522, which is calculated using the standard traffic profiles of Table 1/E.523, may be used.

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3) It may be necessary to calculate transit switching charge per holding minute from charge per conversation minute (efficiency factor is described in Recommendation E.506).

TABLE 1/E.522

Offered traffic (erlangs)	Overflow probability (%)	Time difference												
		0	1	2	3	4	5	6	7	8	9	10	11	12
5	1	2.6	3.2	3.7	3.8	2.7	2.3	2.3	1.7	3.2	2.4	2.2	2.0	2.7
	10	3.7	4.5	4.8	4.7	3.5	3.1	3.0	2.5	4.1	3.2	2.9	2.8	3.6
	20	4.5	5.2	5.4	5.3	4.0	3.7	3.5	3.1	4.7	3.8	3.4	3.4	4.2
	30	5.1	5.8	6.0	5.8	4.6	4.2	4.0	3.7	5.1	4.3	3.9	4.0	4.8
	40	5.7	6.4	6.5	6.3	5.1	4.7	4.5	4.2	5.6	4.8	4.4	4.6	5.3
	50	6.3	6.9	7.0	6.8	5.6	5.2	5.0	4.7	6.0	5.3	5.0	5.1	5.8
10	1	2.1	2.6	3.3	3.5	2.5	2.1	2.1	1.4	2.8	2.0	2.0	1.8	2.4
	10	3.2	4.0	4.4	4.3	3.1	2.7	2.6	2.1	3.8	2.8	2.6	2.4	3.2
	20	4.0	4.8	5.1	4.9	3.6	3.3	3.1	2.7	4.3	3.4	3.0	3.0	3.8
	30	4.7	5.4	5.6	5.4	4.2	3.8	3.6	3.3	4.8	3.9	3.4	3.6	4.4
	40	5.3	6.0	6.1	5.9	4.7	4.4	4.2	3.8	5.3	4.4	4.0	4.2	4.9
	50	5.9	6.6	6.7	6.4	5.3	4.9	4.7	4.4	5.7	5.0	4.6	4.8	5.5
25	1	1.6	2.0	2.8	3.1	2.2	1.8	2.0	1.2	2.4	1.7	1.8	1.6	2.1
	10	2.7	3.3	3.9	3.9	2.7	2.4	2.3	1.7	3.3	2.4	2.3	2.0	2.7
	20	3.5	4.2	4.6	4.4	3.2	2.8	2.7	2.2	3.9	3.0	2.6	2.5	3.3
	30	4.2	5.0	5.2	5.0	3.7	3.4	3.2	2.8	4.4	3.5	3.0	3.1	3.9
	40	4.8	5.6	5.8	5.5	4.3	3.9	3.8	3.4	4.9	4.0	3.5	3.7	4.5
	50	5.5	6.2	6.3	6.1	4.9	4.5	4.3	4.0	5.4	4.6	4.1	4.4	5.1
50	1	1.3	1.7	2.4	2.9	2.1	1.6	2.0	1.1	2.1	1.5	1.6	1.4	2.0
	10	2.3	2.8	3.5	3.6	2.5	2.2	2.1	1.4	3.1	2.2	2.2	1.8	2.4
	20	3.1	3.9	4.3	4.2	3.0	2.6	2.4	1.9	3.7	2.7	2.5	2.2	3.0
	30	3.9	4.7	5.0	4.8	3.4	3.1	2.9	2.5	4.2	3.3	2.8	2.8	3.6
	40	4.6	5.4	5.6	5.3	4.0	3.7	3.5	3.2	4.7	3.8	3.2	3.5	4.3
	50	5.3	6.0	6.1	5.9	4.7	4.3	4.2	3.8	5.2	4.3	3.8	4.2	4.9

Note – Linear interpolation may be used to obtain intermediate results.

The value determined for *R* should then be employed to select in Table 2/E.522 the precise (or next higher) value of annual charges ratio for use in traffic tables. The value of annual charges ratios may be grouped in the following general sets:

a) Within a single continent or other smaller closely connected land mass involving distances up to 1000 miles, high traffic and frequently one-way operation:

Annual charges ratio: R = 1.5; 2.0 ; 3.0; 4.0; 5.0; 6.0 and 7.0[4)]

b) Intercontinental working involving long distances, small traffic and usually two-way operation:

Annual charges ratio: R = 1.1; 1.3 ; 1.5; 2.0; 3.0; 4.0 and 5.0[4)] .

2.5 *Use of method*

High-usage circuit groups carrying random traffic can be dimensioned from Table 2/E.522.

Step 1 – Estimate the annual charges ratio *R* as described under 2.4 above. (There is little difference between adjacent ratios.) If this ratio is difficult to estimate, the values underlined in a) and b) of § 2.4 above, should be used.

Step 2 – Consult Table 2/E.522 to determine the number of high-usage circuits *N*.

Note – When two values of *N* are given the right-hand figure applies to alternative routes of more than 10 circuits, the left-hand figure applies to smaller groups. The left-hand figure is omitted when it is no longer possible for the alternative route to be small.

3 24-hour traffic profiles

The traffic value used in the method in § 2 should be the value of traffic offered to the high-usage route during the busy hour of the final route. In the case that some of the busy hours of the circuit groups or links forming an alternative route do not coincide with the busy hour of the relation, the ensuing method should be followed to take 24-hour traffic profiles into account (see [6], [8] and [9]).

The method consists of the following three basic steps:

i) prepare hourly traffic demands for which dimensioning is to be done;

ii) size all circuit groups, high usage and final, for one hourly traffic demand;

iii) iterate the process in step ii) for each additional hourly matrix.

3.1 *Preparation of hourly traffic demands*

Each Administration gathers historical traffic data on an hourly basis in accordance with Recommendations E.500 and E.523. Using historical data and information contained in Recommendation E.506, hourly traffic demand forecasts are made, resulting in a series of hourly demands for each exchange to every other exchange.

3.2 *Sizing circuit groups for one-hourly traffic demand*

Using the methods in § 2 and Recommendation E.521, trunk group sizes are prepared for the first hourly traffic demand disregarding other hourly traffic demands.

4) These values are tentative. Ranges and representative values of annual charges ratio require further study.

TABLE 2/E.522

Number of high-usage circuits for different values of offered traffic, annual charges ratios and sizes of overflow groups

Traffic offered during network busy hour (erlangs)	Annual charges ratios									Number of circuits if there is no overflow route, for $p = 0.01$
	1.1	1.3	1.5	2.0	3.0	4.0	5.0	6.0	7.0	
	Minimum circuit occupancies for high-usage traffic									
	0.545/0.727	0.46/0.615	0.4/0.53	0.3/04	0.2/0.26	0.15/0.2	0.12/0.16	0.0/0.13	0.085/0.114	
	N, number of high usage circuits *A/B*, where *A* is for less than 10 circuits in the overflow group (*M* = 0.6) *B* is for 10 or more circuits in the overflow group (*M* = 0.8)									
1.5	1/0	1/0	2/1	2/2	3/2	3/3	4/3	4/3	4/4	6
1.75	1/0	2/1	2/1	3/2	3/3	4/3	4/4	4/4	4/4	6
2.0	1/0	2/1	2/2	3/2	4/3	4/4	4/4	5/4	5/5	7
2.25	2/0	2/1	3/2	3/3	4/4	5/4	5/4	5/5	5/5	7
2.5	2/0	3/1	3/2	4/3	5/4	5/5	5/5	6/5	6/5	7
2.75	2/1	3/2	3/2	4/3	5/4	5/5	6/5	6/6	6/6	8
3.0	3/1	3/2	4/3	4/4	5/5	6/5	6/6	6/6	7/6	8
3.5	3/1	4/2	4/3	5/4	6/5	7/6	7/6	7/7	7/7	9
4.0	4/2	4/3	5/4	6/5	7/6	7/7	8/7	8/7	8/8	10
4.5	4/2	5/3	6/4	6/6	7/7	8/7	8/8	9/8	9/8	10
5.0	5/3	6/4	6/5	7/6	8/7	9/8	9/9	9/9	10/9	11
5.5	5/3	6/5	7/5	8/7	9/8	9/9	10/9	10/10	10/10	12
6.0	6/3	7/5	7/6	8/7	9/9	10/9	11/10	11/10	11/11	13
7.0	7/4	8/6	8/7	10/8	11/10	11/11	12/11	12/12	13/12	14
8.0	8/5	9/7	10/8	11/10	12/11	13/12	13/13	14/13	14/13	15
9.0	/6	/8	/9	/11	/12	/13	/14	/14	/15	17
10.0	/7	/9	/10	/12	/14	/15	/15	/16	/16	18
12.0	/9	/11	/12	/14	/16	/17	/18	/18	/19	20
15.0	/12	/14	/16	/18	/20	/21	/21	/22	/22	24
20.0	/16	/19	/21	/23	/25	/27	/28	/28	/29	30
25.0	/21	/24	/26	/29	/31	/33	/33	/34	/35	36
30.0	/26	/29	/31	/34	/37	/38	/39	/40	/41	42
40.0	/36	/39	/42	/45	/48	/50	/51	/52	/52	53
50.0	/45	/49	/52	/55	/59	/61	/62	/63		64
60.0	/55	/60	/62	/66	/70	/72	/73			75
80.0	/74	/80	/83	/87	/92	/94	/95			96
100.0	/94	/100	/103	/108	/113	/116				117
120.0	/113	/120	/124	/129	/134	/137	Direct final circuit groups are			138
150.0	/143	/150	/154	/160	/166	/169	economical within this area.			170
200.0	/192	/200	/205	/212	/219					221
250.0	/241	/250	/256	/263	/271					273
300.0	/290	/300	/306	/315	/323					324

3.3 *Iterating for each additional hourly traffic matrix*

In sizing the circuit groups for the second hourly traffic demand, the method is provided with the circuit quantities resulting from the previous step, and is constrained solely to increasing circuit group sizes; i.e., if the circuit group sizes for the first hourly traffic demand were greater than for the second hourly demand, then the circuit group sizes for the first hourly traffic demand would be retained.

All additional hourly traffic demands are processed in the same iterative manner. The resulting circuit group sizes then satisfy the traffic demands for all hours being considered (see Annex A for a computational example).

3.4 *Processing sequence*

Processing may start with the first hour of traffic demand, however, experiments have indicated that efficiencies of the network can be improved if processing starts with the hour with the smallest total traffic demand. It should be noted that this method gives us suboptimal networks, which may be improved by manual refinements.

4 Minimum outlay alternate routing networks

The method below allows Administrations to adjust alternate routing networks to take into account existing revenue accounting divisions.

The method consists of the following steps:

i) Obtain 24-hour traffic profiles in accordance with Recommendations E.500 and E.523;

ii) Compute circuit quantities and costs for a no-overflow network in accordance with Recommendation E.520;

iii) Compute monthly overflow minutes (holding time) at varying percentages of busy-hour overflow. This is done by applying three conversion factors to the busy hour overflow erlangs:

- Ratio of holding minutes to erlangs: a fixed value of 60.
- Daily overflow to busy-hour overflow ratio: a value that depends on the 24-hour traffic profile and the degree of overflow.
- Monthly overflow to daily overflow ratio (Recommendation E.506): a value that depends on the day-to-day pattern within a month and the degree of overflow.

iv) Starting with the network calculated in step ii):

- reduce the high usage circuits by one circuit,
- calculate overflow to final circuit groups,
- dimension final circuit groups in accordance with Recommendation E.521,
- calculate circuit costs and transit charges;

v) Iterate step iv) until the minimum outlay (circuit costs plus transit charges) for terminal administrations is reached (see Annex B for computational example).

5 Service considerations

On intercontinental circuits, where both-way operation is employed, a minimum of two circuits may be economical. Service considerations may also favour an increase in the number of direct circuits provided, particularly where the annual charges ratio approaches unity.

Although the dimensioning of high-usage groups is normally determined by traffic flows and annual charges ratios, it is recognized that such groups form part of a network having service requirements relative to the subscriber. The ability to handle the offered traffic with acceptable traffic efficiency should be tempered by the overall network considerations on quality of service.

The quality of service feature, which is of primary importance in a system of high-usage and final circuit groups, is the advantage derived from direct circuits versus multi-link connections. A liberal use of direct high-usage circuit groups, taking into account the economic factors, favours a high quality of service to the subscriber. It is recommended that new high-usage groups should be provided whenever the traffic flow and cost ratios are not conclusive. This practice may result in direct high-usage groups of two circuits or more.

The introduction of high-usage groups improves the overall grade of service and provides better opportunities of handling traffic during surges and breakdown conditions. When high-usage links bypass the main final routes the introduction of high-usage routes can assist in avoiding expenses which might otherwise be incurred in keeping below the maximum number of long-distance links in series. In the future, more measurements of traffic flows may be necessary for international accounting purposes and high-usage circuits should make this easier.

ANNEX A

(to Recommendation E.522)

Example of network dimensioning taking into account
24-hour traffic profiles

A.1 *Assumptions* (see also Figure A-1/E.522)

Calculations are performed under the following conditions:

1) Time difference:

A is 9 hours west of B

C is 5 hours west of A

B is 10 hours west of C

2) Traffic profiles:

24-hour traffic profiles as per Table l/E.523 are used.

3) Busy hour traffic:

A-B 50 erlangs

A-C 100 erlangs

C-B 70 erlangs

4) Cost ratio:

$R = 1.3$

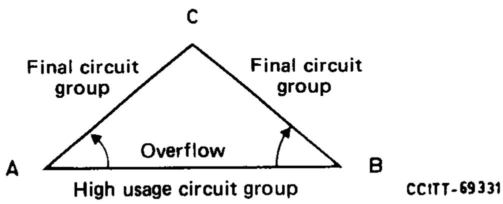

FIGURE A-1/E.522

Triangular network for numerical examples (Example 1)

A.2 *Numerical results*

24 hourly traffic demands are processed. The order of processing are from the hour with the smallest total traffic demand to the hour with the largest total traffic demand. Computational results are given in Table A-1/E.522.

TABLE A-1/E.522

Numerical results

Hour	Hourly traffic demand			Number of circuits obtained by single hour dimensioning (disregarding lower bounds imposed by the previous iterative stage)			Number of circuits obtained considering lower bounds imposed by the previous iterative stage			Number of circuits required to meet multiple hourly traffic demands		
	A-B	A-C	C-B	A-B	A-C	C-B	A-B	A-C	C-B	A-B	A-C	C-B
6	17.50	5.00	3.50	17	19	17	17	19	17	17	19	17
7	20.00	5.00	3.50	19	20	18	19	20	18	19	20	18
5	2.50	5.00	28.00	1	14	41	19	11	39	19	20	39
4	2.50	5.00	35.00	1	14	49	19	11	47	19	20	47
8	37.50	5.00	3.50	37	23	22	19	38	37	19	38	47
9	40.00	5.00	3.50	39	24	23	19	41	40	19	41	47
3	2.50	5.00	45.50	1	14	61	19	11	59	19	41	59
18	2.50	50.00	3.50	1	66	12	19	64	9	19	64	59
10	50.00	5.00	3.50	49	26	25	9	61	59	19	64	59
19	2.50	60.00	3.50	1	77	12	19	75	9	19	75	59
20	2.50	60.00	3.50	1	77	12	19	75	9	19	75	59
22	12.50	30.00	24.50	12	45	39	12	45	39	19	75	59
2	2.50	5.00	63.00	1	14	80	19	11	78	19	75	78
17	2.50	70.00	3.50	1	87	12	19	85	9	19	85	78
1	2.50	5.00	70.00	1	14	87	19	11	85	19	85	85
23	20.00	20.00	42.00	19	36	60	19	36	60	19	85	85
11	47.50	25.00	17.50	47	46	38	3	85	77	19	85	85
21	12.50	55.00	24.50	12	73	39	12	73	39	19	85	85
12	42.50	30.00	21.00	42	50	41	3	85	76	19	85	85
16	2.50	90.00	3.50	1	109	12	19	107	9	19	107	85
0	20.00	20.00	66.50	19	36	87	19	36	87	19	107	87
13	30.00	65.00	35.00	29	86	54	5	107	76	19	107	87
15	17.50	100.00	28.00	17	121	44	19	120	43	19	120	87
14	27.50	95.00	38.50	27	117	57	19	124	64	19	124	87

This example relates to an intercontinental network where busy hours of the three traffic relations are widely different among each other. The busy hour of the relation A-C, i.e. hour 15, is a low traffic period for the relations A-B and C-B. The busy hour of the relation C-B, i.e. hour 1, is a low traffic period for the relations A-B and A-C. Similarly, the busy hour of the relation A-B, i.e. hour 10, is a low traffic period for the relations A-C and C-B.

In this case, the single hour dimensioning method, where traffic data during the busy hour of the final circuit group are used for dimensioning, cannot be applied. If the single hour dimensioning method is applied, this results in considerable under-dimensioning.

If all the circuit groups are dimensioned as final, the required number of circuits are 64, 117 and 85 for the circuit groups A-B, A-C and C-B, respectively. About 14% of the total number of circuits is saved by the use of alternate routing.

ANNEX B

(to Recommendation E.522)

Example of minimum outlay network dimensioning

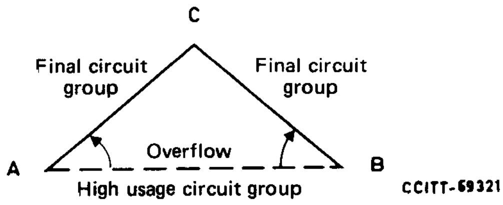

FIGURE B-1/E.522

Triangular network for numerical example (Example 2)

B.1 *Assumptions* (see also Figure B-1/E.522)

Calculations are performed under the following conditions:

1) Time difference:

A is 3 hours west of B
A is 3 hours west of C
No time difference between B and C

2) Traffic profiles:

24-hour traffic profiles as per Table 1/E.523 are used.

3) Busy hour traffic:

A-B 16 erlangs
A-C 33 erlangs
C-B 33 erlangs

4) Each Administration monthly cost per circuit:

A-B 1000 units
A-C 1000 units
C-B 800 units

5) Transit charge per holding minute to each terminal Administration:

1/2 unit

6) Conversion factors:

i) Holding minutes/erlangs: 60

ii) Daily overflow/busy hour overflow

This conversion factor (*F*) is calculated according to the guideline given in § 2.4.

iii) Monthly overflow/daily overflow: 26

where medium social contact per Recommendation E.502 is assumed.

7) Grade-of-service (GOS) on final circuit groups: 0.01

B.2 *Numerical results*

Numerical results are shown in Table B-1/E.522. The number of circuits C-B does not increase because of the 24-hour traffic profiles matching. The number of high usage circuits A-B in the minimum outlay network is larger than that in the minimum cost network. The impact of considering transit charges in dimensionings is always in the direction of less overflow.

TABLE B-1/E.522

Numerical results

Network results				Economic results (× 1000 units/month)								
Busy-hour overflow probability	Number of circuits			Circuits costs			Transit charges			Total outlay		
	A-B	A-C	C-B	A	B	C	A	B	C	A	B	C
0.0000	25	45	45	70	61	81	–	–	–	70.0	61.0	81.0
0.0090	25	45	45	70	61	81	0.3	0.3	(0.7)	70.3	61.3	80.3
0.0151	24	45	45	69	60	81	0.6	0.6	(1.3)	69.6	60.6	79.7
0.0221	23	45	45	68	59	81	0.9	0.9	(1.9)	68.9	59.9	79.1
0.0331	22	46	45	68	58	82	1.4	1.4	(2.9)	69.4	59.4	79.1
0.0471	21	46	45	67	57	82	2.1	2.1	(4.2)	69.1	59.1	77.8
0.0641	20	46	45	66	56	82	3.0	3.0	(6.0)	69.0	59.0	76.0
										Minimum outlay for A and B		
0.0861	19	47	45	66	55	83	4.2	4.2	(8.4)	70.2	59.2	74.5
0.1121	18	47	45	65	54	83	5.7	5.7	(11.5)	70.7	59.7	71.5
										Minimum cost network		
0.142	17	48	45	65	53	84	7.6	7.6	(15.1)	72.6	60.6	68.9
0.175	16	49	45	65	52	85	9.7	9.7	(19.4)	74.7	61.7	65.6

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