Subscriber And Traffic Forecasting

For A Rural Network

Case Study

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CASE STUDY

SUBSCRIBER AND TRAFFIC FORECASTING FOR A RURAL NETWORK

1. Traffic Forecasting Principles For Rural Networks

Bearing in mind that:

- for planning purposes, rural networks are usually divided into two hierarchical levels;
- the switching units on the lowest level are generally small or very small and are hierarchically connected only to a combined exchange on the higher level;
- villages and towns are often of very different type as to size, economic activities, stages of development, development trends, etc.;

we should try to:

- forecast outgoing, incoming, and internal traffic for each village;
- forecast inter-area traffics on the higher level;
- forecast number of subscribers for each village and town;
- in general, forecast per village type rather than per subscriber class.

2. The Specific Case

The actual rural area is a district with a district centre which communicates with the outer world. The district is divided into 18 communes. The commune centres are towns where combined exchanges are located. Each commune centre has a hierarchical network which reaches out to its villages. There are a total of 264 villages.

The data we have consist of:

Commune and village population figures for 5 years ago, for the present and forecasts for the next 5, 10, and 15 years. We also have figures on connected and waiting subscribers for 5 years ago, and for the present. We have the present traffic matrix for communes, and the LD-traffic. In addition, there is general information on the district, the communes, and some towns and villages. Furthermore, the administration has attempted to classify the different villages according to status and expected development of subscriber density and calling rates.

3. Your Task

Your task is to forecast the number of future subscribers per village and per town, the inter-commune traffic matrix and the LD-traffics, as well as the traffics for each village and town.

The recommended work procedure involves considerable individual thought, subjective judgement and decisions without which the forecast cannot be completed properly. Please note that, optionally, you are free to include even more subjective judgement. You are expected to produce a written report showing not only the final forecasts, but also the intermediate result in the form of tables with an explanation of what problems you faced and your discussions and decisions on these problems, i.e., what kind of individual decisions you made and your reasons for making them.

4. Work Procedure Overview

(1) Forecast the number of future connected subscribers per village and town, applying an exponential logistic function to historical data for population and subscribers, in conjunction with your opinion on the size of the future waiting lists.
Individual opinions should be based on the work already done by the administration, on density development, and on the general descriptions of the district, the communes, and the villages.

(2) Forecast calling rates per village by checking experts' opinions against available traffic records.

(3) Forecast total traffics per commune by using the subscriber forecast and the calling rate forecast per village, combined with the classification table of villages.

(4) Forecast LD-traffic per commune by some reasonable method.

(5) Remove forecasted LD-traffics from the matrix.

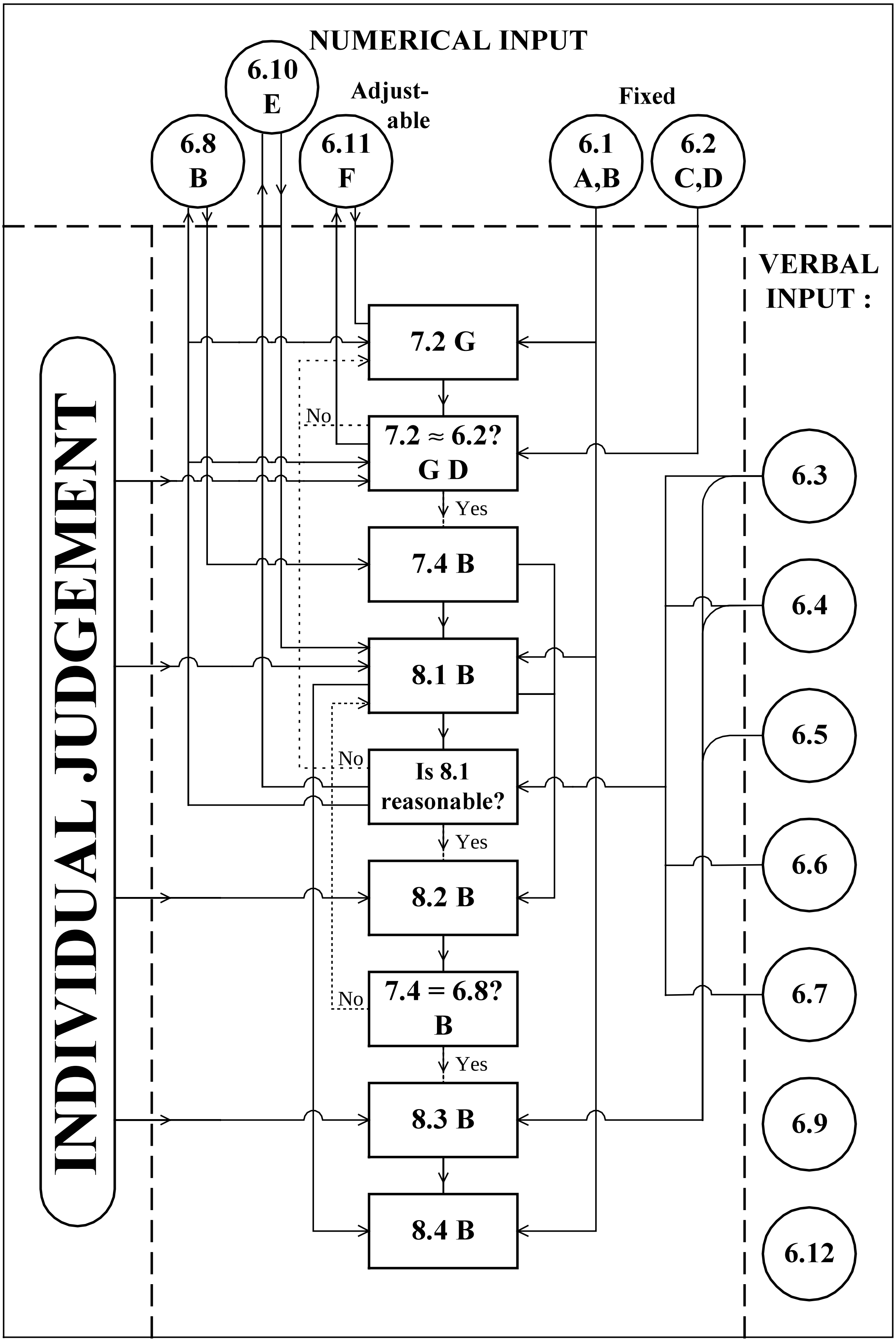
(6) Forecast point-to-point traffics between communes using Affinity, Weighted Growth, or some other method.

(7) Reconcile the point-to-point traffics with the total traffics.

(8) Forecast originating, terminating and internal village traffics by using the calling rates and the number of subscribers.

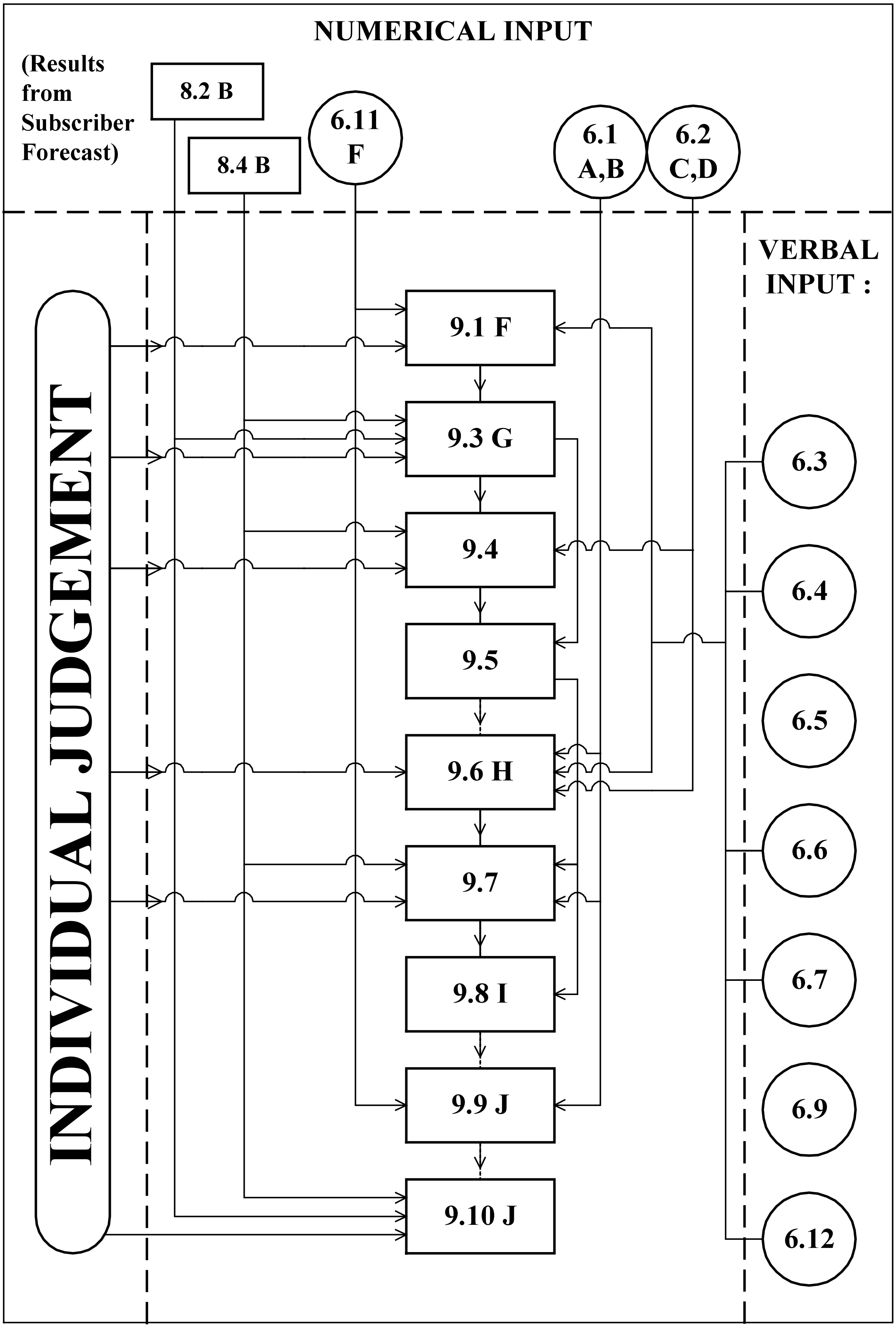
(9) Check that the two traffic forecasts, viz. the traffic matrix for communes and the originating, terminating, and internal traffics per village agree reasonably well. If not, parts of the work procedure have to be repeated in the the light of the result of the check.

The required forecasts consist of the results from (1), (4), (7) and (8).



FORECAST PROCESS
1. Preparatory calculations, and subscriber forecast

<u>Numbers</u> refer to chapters in this document.
<u>Letters</u> refer to computerized data sheets shown in this document.
———→ means “proceed” or “go back”



FORECAST PROCESS
2. Traffic forecast

Numbers refer to chapters in this document.
Letters refer to computerized data sheets shown in this document.
———→ means "proceed" or "go back"

In order to use these flow charts, there are many points that needto be dicussed and decided. A check list with some of the most important points is given below:

CHECK LIST

Important activities and decisions

ITEM	ACTIVITIES AND DECISIONS
TC - values	
DMAX	
TCR, PO, PI	
% connected Subs for T = 5, 10, 15	
Traffic forecast method for point - to - point traffics	
Traffic forecast method for LD - traffics	
Other studies	
Conclusions	

5. Variables

P	= Population
N	= No. of connected subscribers
L	= No. of subscribers on waiting List
A	= Traffic
TCR	= Total calling rate
PO	= Proportion originating traffic
PI	= Proportion internal traffic
DMAX	= Maximum penetration = saturation limit
PN	= Proportion connected subscribers
TC	= Traffic category
Y	= Ratio penetration to maximum penetration
D	= Penetration
M	= Curve constant (density forecast)
C	= " " " "
TW	= " " " "
YW	= " " " "
AOH	= Hypothetical originating commune traffic
ATH	= Hypothetical terminating commune traffic
AO	= Originating traffic
AT	= Terminating traffic
AI	= Internal traffic
AOI	= Outgoing traffic, intelligent concentrators
ATI	= Incoming traffic " "
AII	= Internal traffic " "
F	= Affinity factors
AF	= Final traffic (some internal traffics removed)

<u>Subscripts</u>

c	= Commune no.
v	= Village no.
(T)	= point of time
i,j	= Commune no.
(0)	= Present time
D	= District
L	= LD
T	= Terminating
O	= Originating
TC	= Traffic category

6. **Basic Data**

6.1 Population and subscriber data

Place		Population					Connected Subs.		Waiting Subs.	
COMMUNE **C**	VILLAGE **V**	$P_V(T)$					$N_V(T)$		$L_V(T)$	
		T = -5	T = 0	T = 5	T = 10	T = 15	T = -5	T = 0	T = -5	T = 0

The data is stored in the computer and the corresponding print-outs, data sheets A and B, look like this:

A

D:01			010101						
C:0101			1010101						
M:300000.	0.0	0.0		**T=**	**- 5**	**0**	**5**	**10**	**15**
P01 01 01			23.033.3		54090	61290	67050	71850	75200
P01 01 03			25.735.1		260	260	250	240	220
P01 01 04			25.933.7		145	140	130	120	100
P01 01 07			25.232.5		100	90	80	70	60
P01 01 08			24.131.4		240	200	190	170	160

c, v — $P_V(T)$

B

Village	Cat	N_v-5	L_v-5	N_v 0	L_v 0	ND_v 5	ND_v10	ND_v15	% 5	%10	%15
P01 01 01	0000	12680	1200	16220	1360	0	0	0	1.00	1.00	1.00
P01 01 03	4444	21	5	24	7	0	0	0	1.00	1.00	1.00
P01 01 04	4444	7	2	10	2	0	0	0	1.00	1.00	1.00
P01 01 07	4444	3	0	3	0	0	0	0	1.00	1.00	1.00
P01 01 08	4444	17	2	18	3	0	0	0	1.00	1.00	1.00

c, v — $N_v(T)$, $L_v(T)$ (T = - 5, 0)

Optionally, you can aggregate village data into commune data:

Commune	P_C (T)					N_C (T)		L_C (T)	
C	T = - 5	T = 0	T = 5	T = 10	T = 15	T = - 5	T = 0	T = - 5	T = 0

$$P_C(T) = \sum_{V \in C} P_V(T)$$

$$N_C(T) = \sum_{V \in C} N_V(T)$$

$$L_C(T) = \sum_{V \in C} L_V(T)$$

This table is not presented on the computer, so if you would like to have it, you will have to do the calculations independently.

6.2 Present Traffic Matrix For Communes

i \ j	1	2	- - -	Σ	LD	Σ
1		A_{ij} (0)		A_{iD} (0)	A_{iL} (0)	A_{iO} (0)
2						
- - -						
Σ		A_{Dj} (0)		A_{DD} (0)	A_{DL} (0)	A_{DO} (0)
LD		A_{Lj} (0)		A_{LD} (0)	0	- - -
Σ		A_{Tj} (0)	A_{TD} (0)		- - -	A_O (0) / A_T (0)

The matrix is stored in the computer. Point - to - point traffics and LD - traffics are shown in data sheet C, below, and total traffics are shown in data sheet D.

C

18 Communes — $A_{ij}(0)$

766.1	18.7	3.9	2.1	1.7	13.5	1.4	9.7	6.9	3.8	**i = 1**
9.5	1.4	1.3	4.0	4.0	2.6	1.2	0.2	57.3		
37.6	263.4	3.2	1.7	1.4	11.3	1.2	8.1	5.7	3.2	**i = 2**
7.9	1.2	1.1	3.3	3.3	2.1	1.0	0.1	23.3		
11.0	4.6	42.2	0.5	0.4	3.3	0.3	2.4	1.7	0.9	**i = 3**
2.3	0.4	0.3	1.0	1.0	0.6	0.3	0.1	3.4		
								$A_{iL}(0)$		

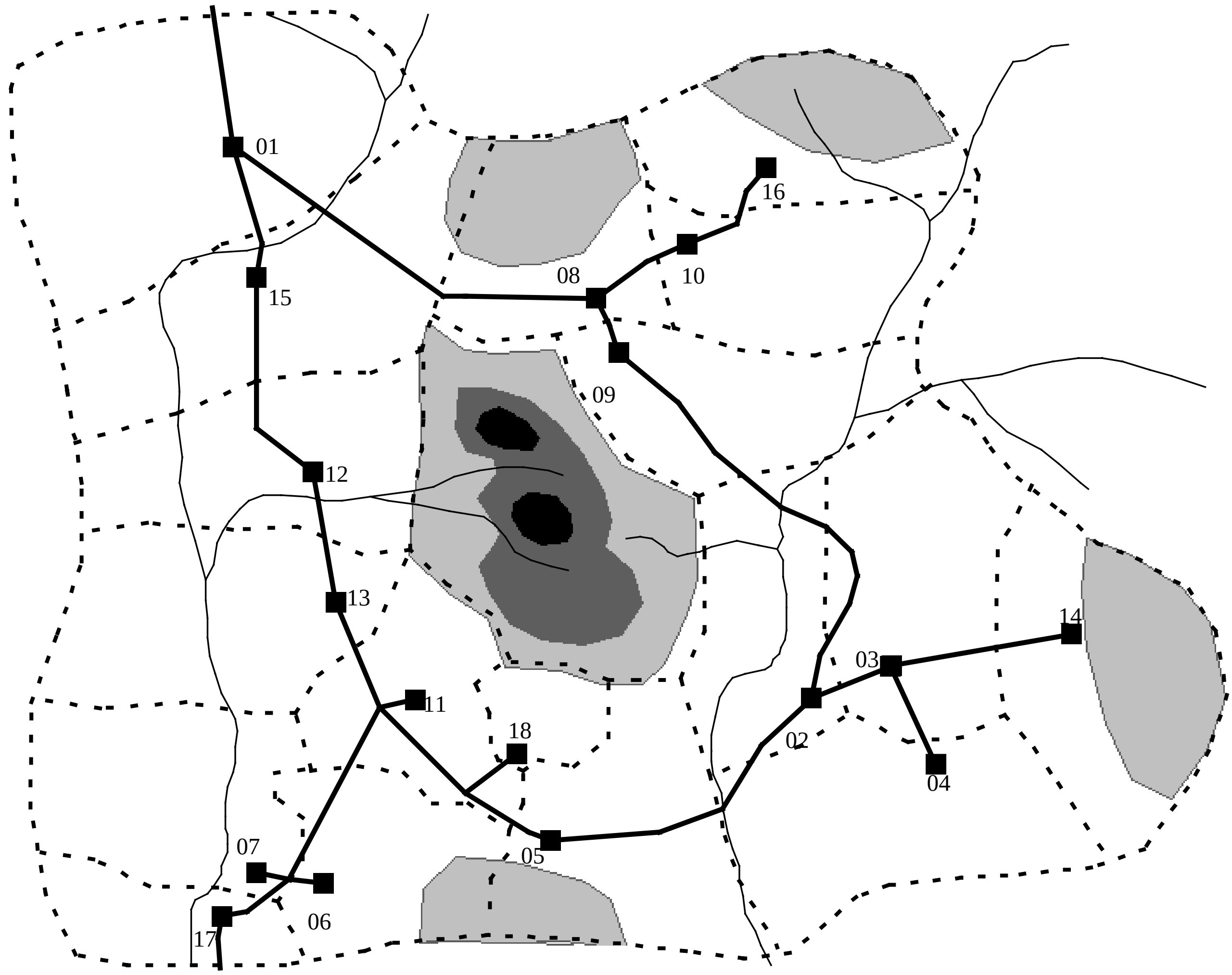
D

	$A_{iD}(0)$	$A_{Dj}(0)$	$A_{iL}(0)$	$A_{Lj}(0)$	$A_{iO}(0)$	$A_{Tj}(0)$
Commune	Originating	Terminating	LD - out	LD - in	Tot - orig	Tot - term
1	852.0	952.8	57.3	51.5	909.3	1004.3
2	356.8	344.8	23.3	22.5	380.1	367.3
3	73.3	61.2	3.4	2.7	76.7	63.9
4	39.5	27.9	1.1	0.9	40.6	28.8

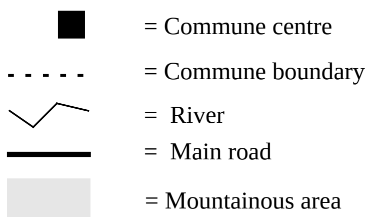
6.3 General Description of the District

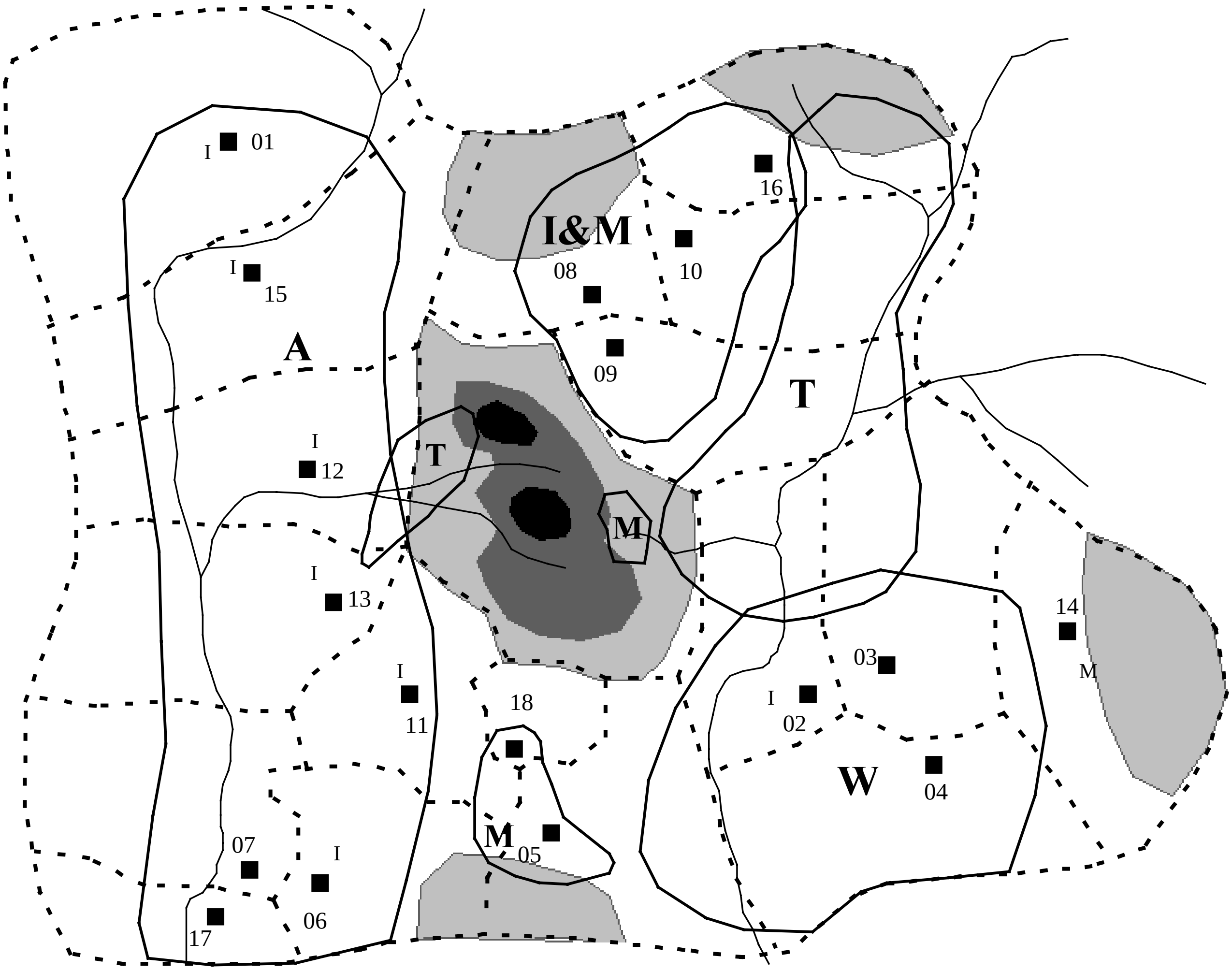
The district is located in a mountainous part of the country. There is a central, uninhabited region with very high, wild mountains, well-known for their beauty and consequently attracting some tourists. There are also rather high mountains in the north-east and south-east corners of the district. A beautiful, sunny valley runs from north to south, with a fast-running sweet water river flowing through it, reputed for good fishing. In the west, there is another flat valley with a river running through it, but this river is broad and slow. Activities in this district are mainly agricultural. The western plain is particularly suited to farming. The larger towns, however, boast of a well-developed and diversified industry.The southern part of the eastern plain is a wine growing area. The wine produced here is of very high quality and the export incomes from this activity have been steadily increasing every year.

We find mining areas, to a limited extent, in the southern and central mountains, and more developed and larger mining industries in the north-east corner, which is also fairly highly industrialized.



Present topology





Present Main Economic Structure

A = Agriculture

I = Industry

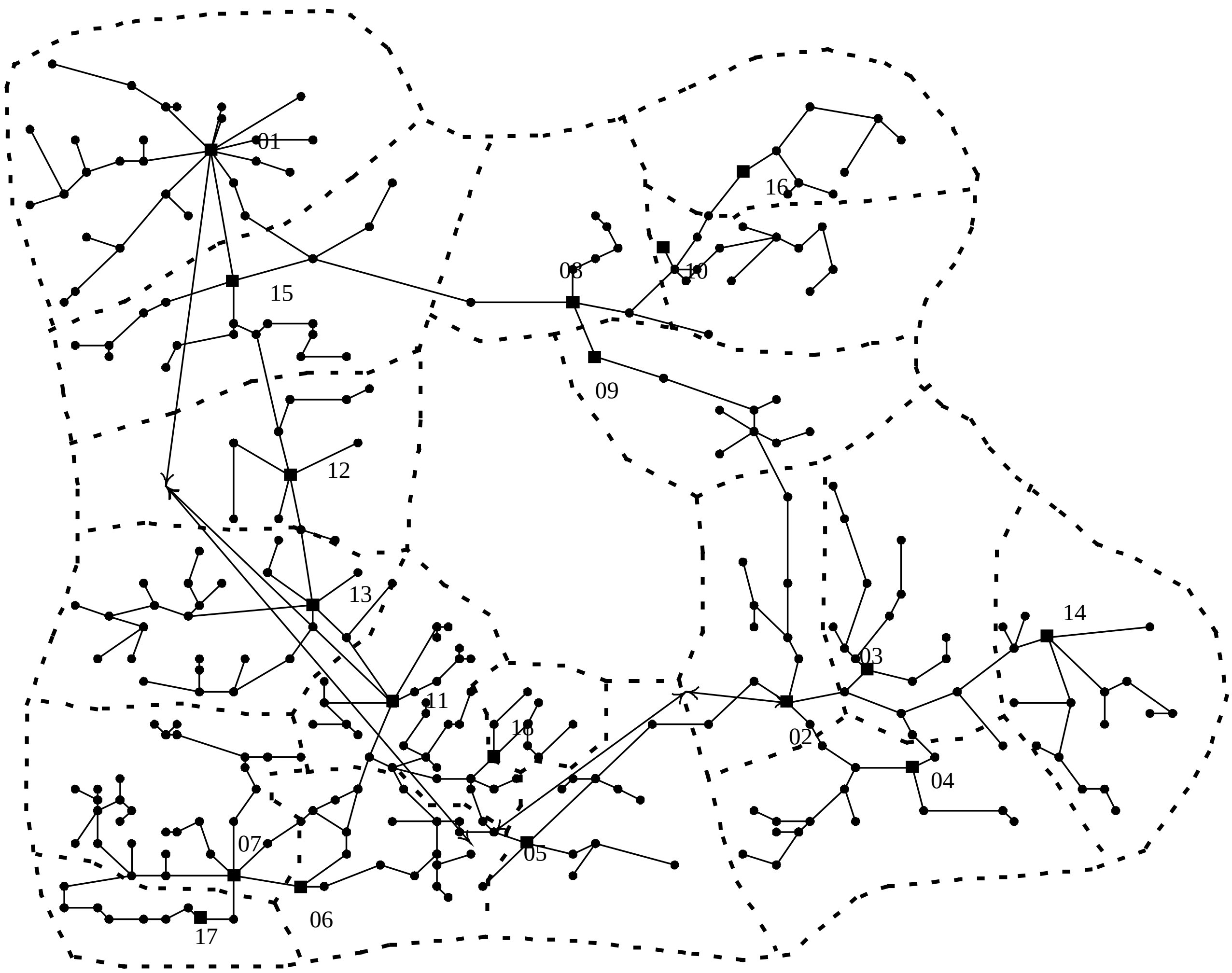
M = Mining

W = Wine-growing

T = Tourism

Present Population Distribution

●	50,000 -
●	10,000 - 50,000
•	3,000 - 10,000
•	1,000 - 3,000
○	500 - 1,000
·	100 - 500
·	1 - 100

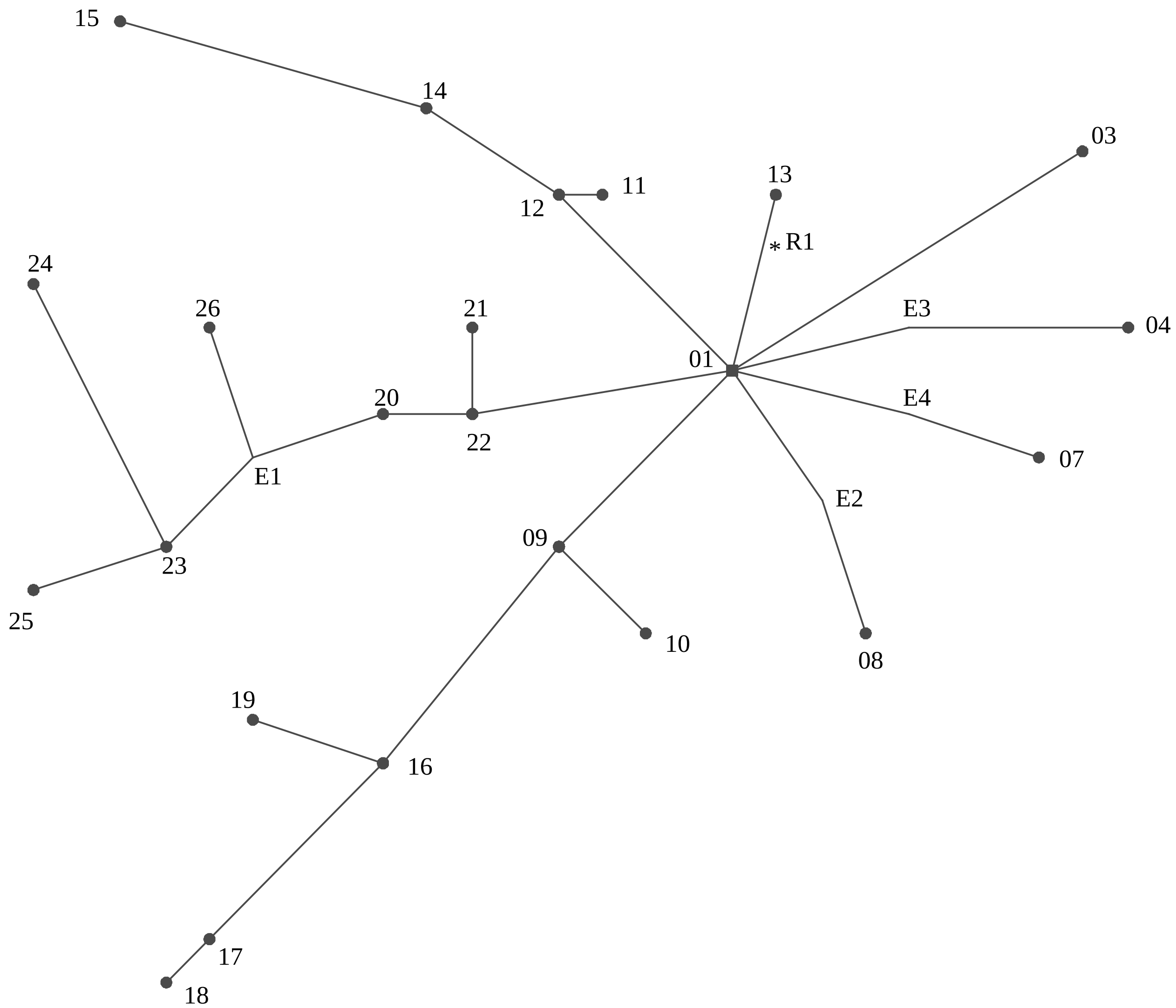


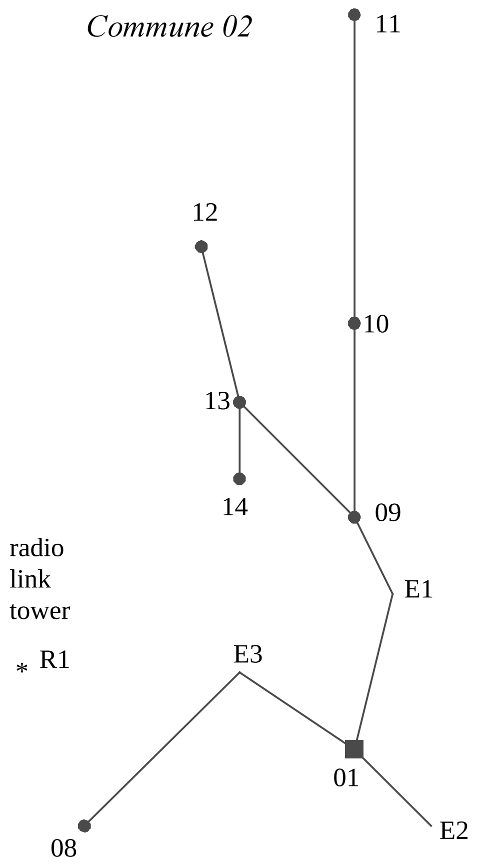
Present Network

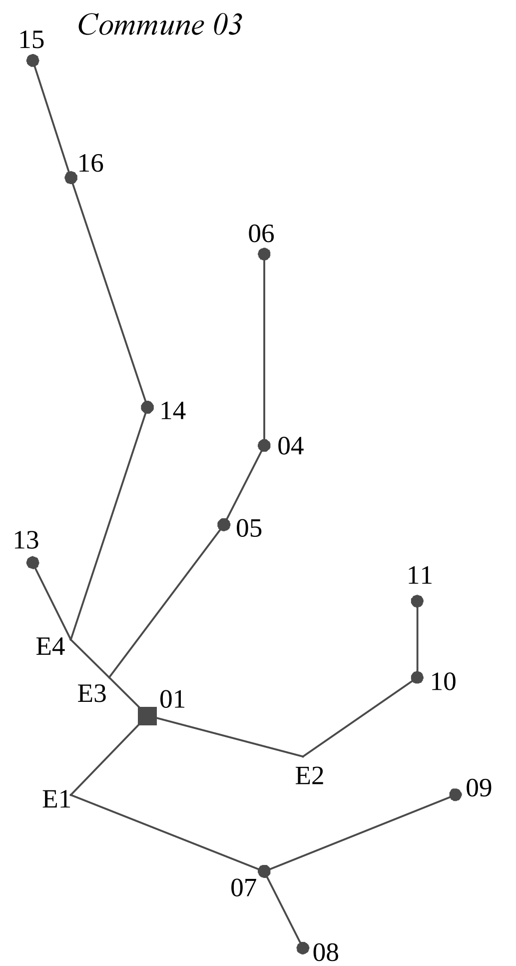
- ● = Populated area
- ■ = Commune centre
- ⋯ = Commune boundary
- ── = Cable

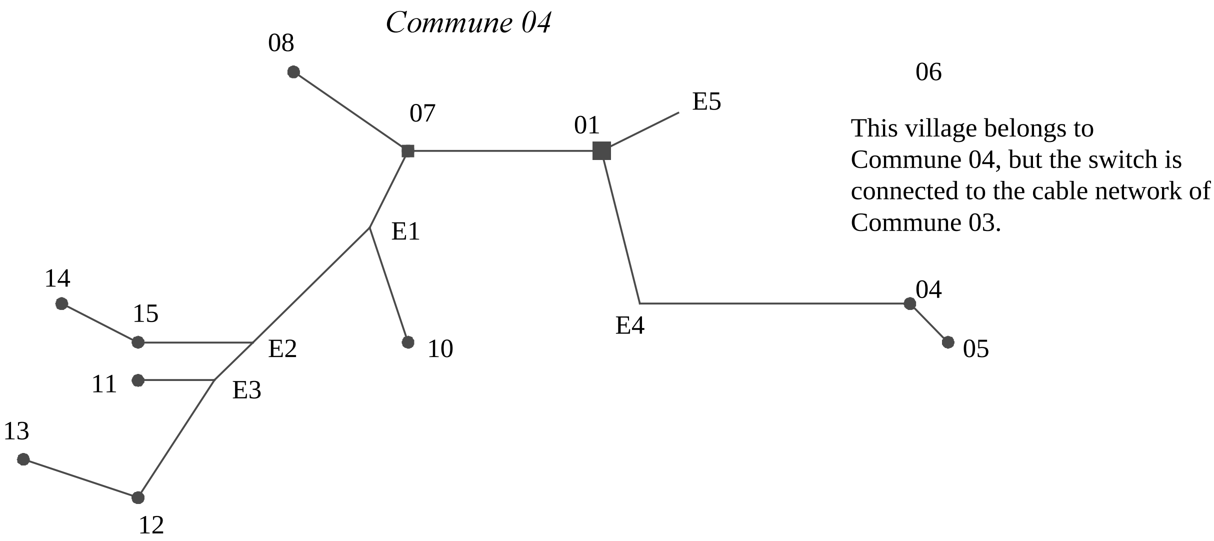
PRESENT NETWORKS PER COMMUNE (01 - 18)

Commune 01

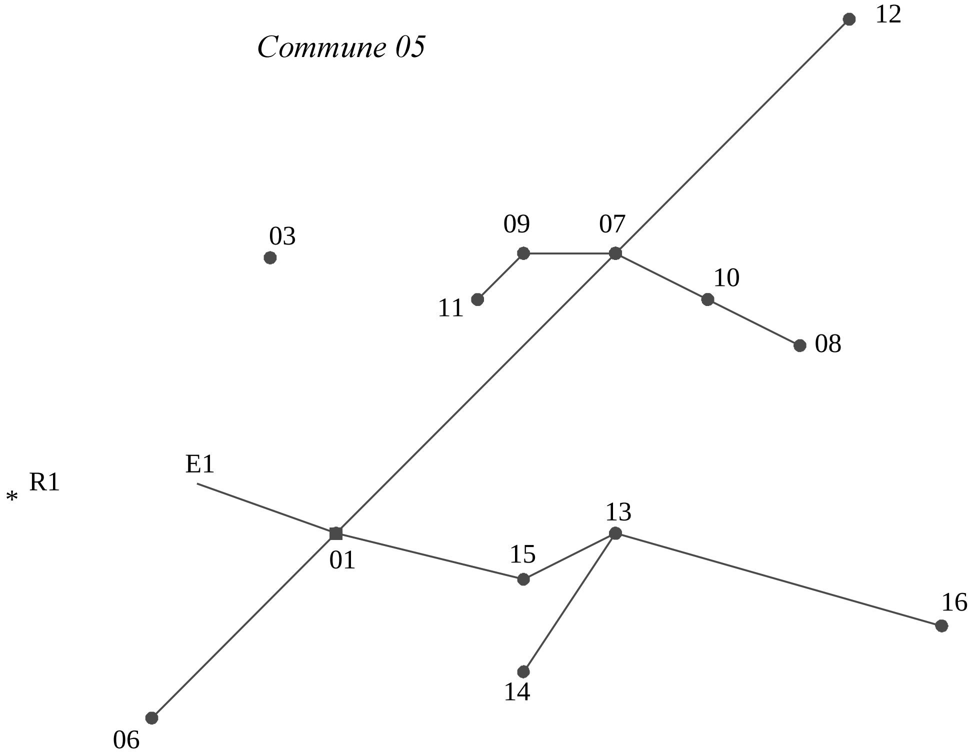



Commune 02
11
12
10
13
14
09
radio
link
tower
E1
* R1
E3
01
08
E2

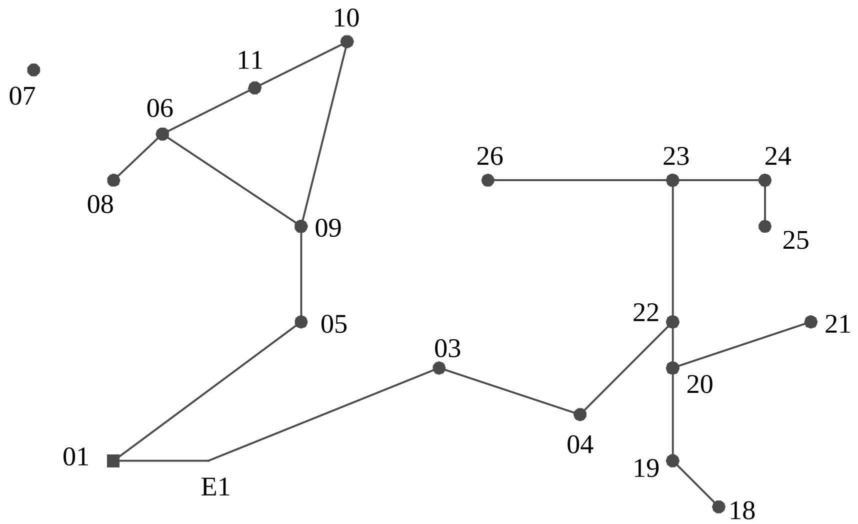

Commune 03
15
16
06
14
04
05
13
11
E4
E3
01
10
E2
E1
09
07
08


Commune 04
08
07
01
E5
06
This village belongs to Commune 04, but the switch is connected to the cable network of Commune 03.
E1
14
15
E2
10
E4
04
05
11
E3
13
12

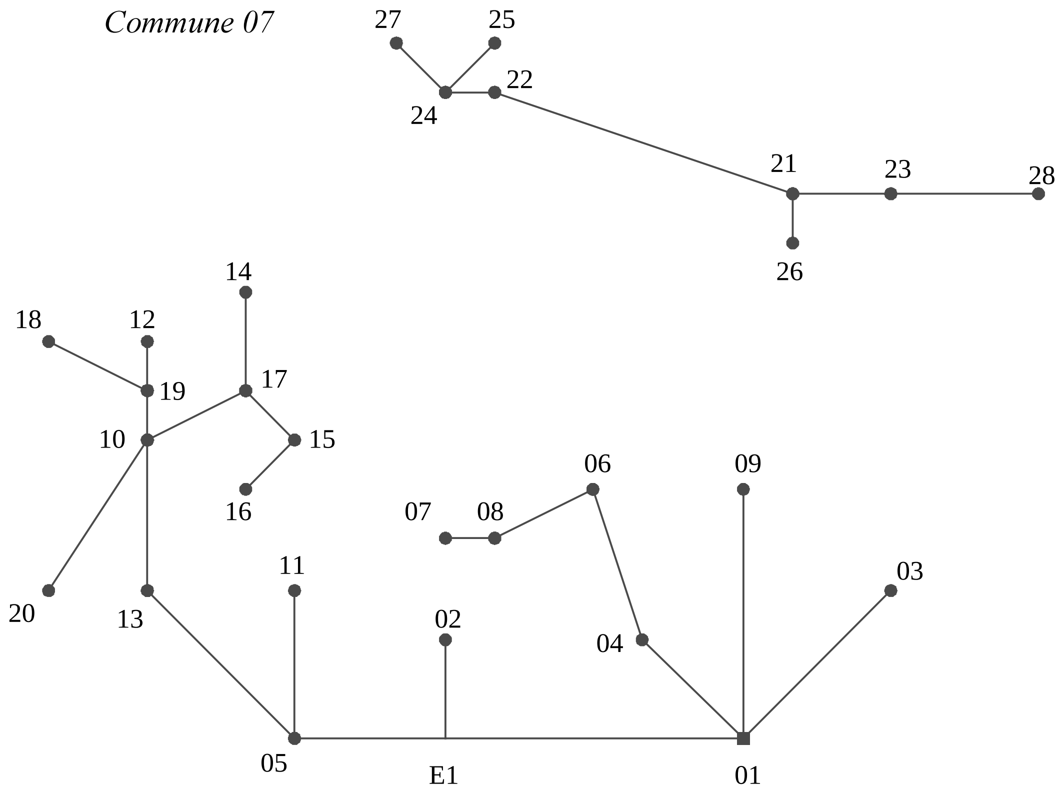
Commune 05



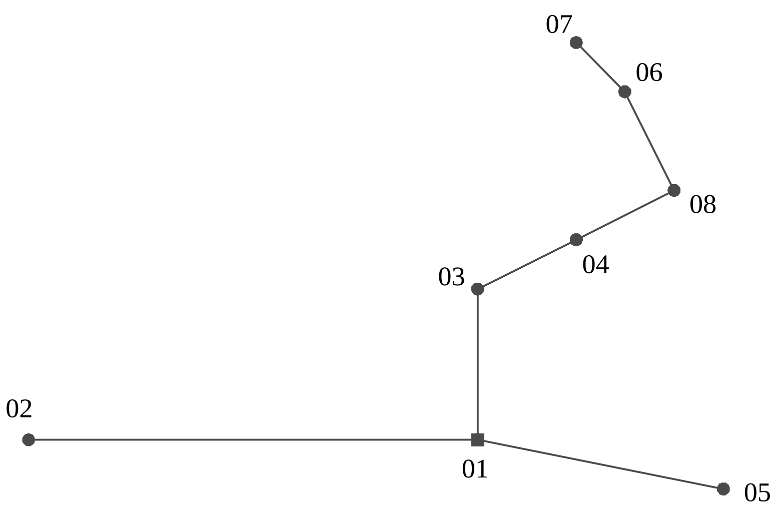
Commune 06



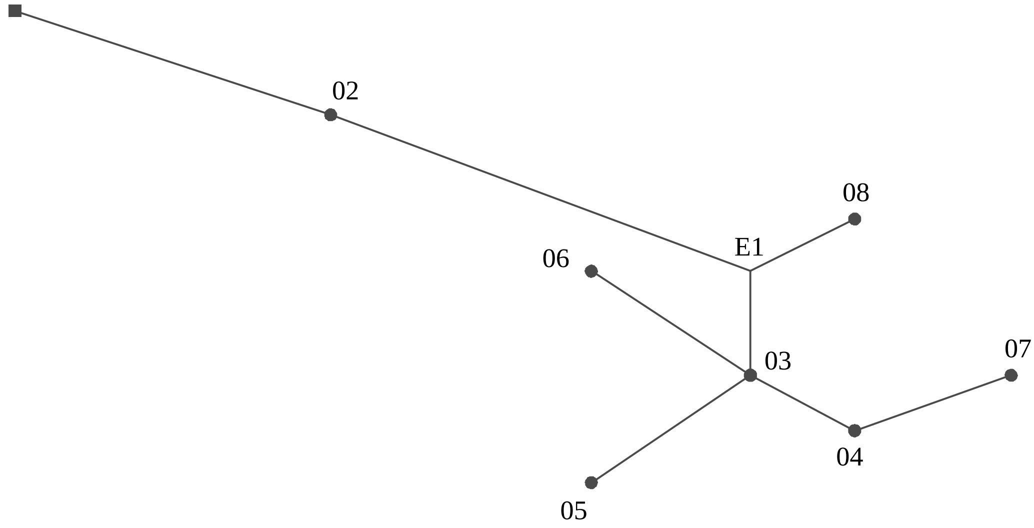
Commune 07



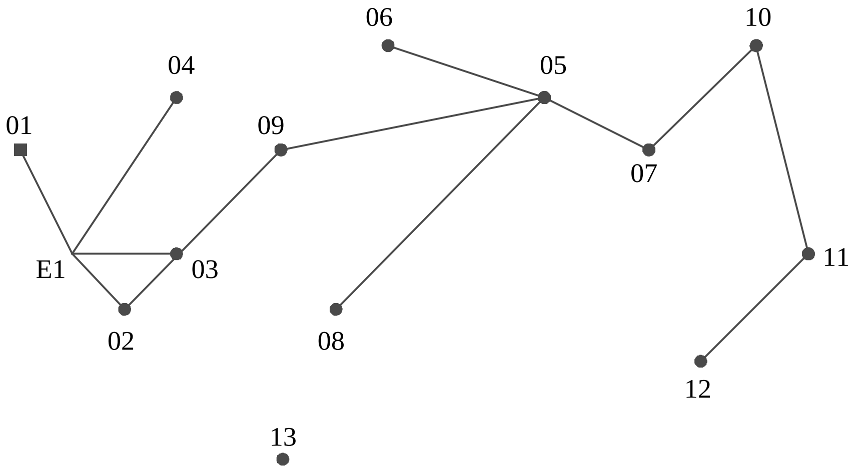
Commune 08

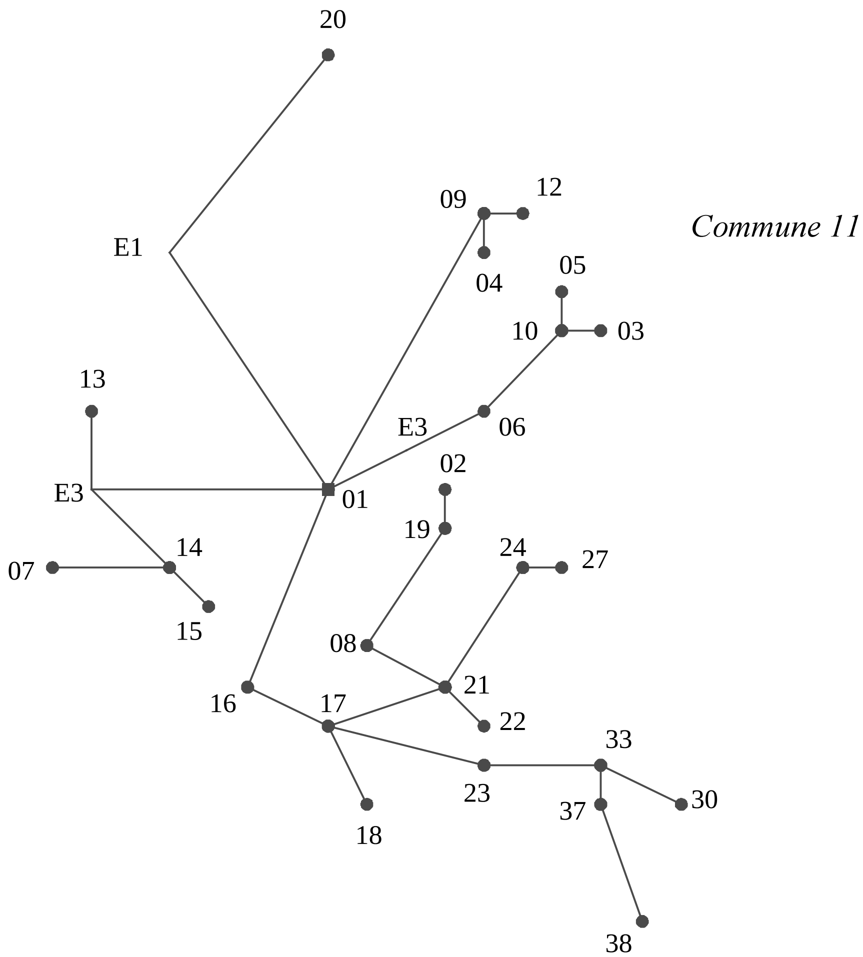


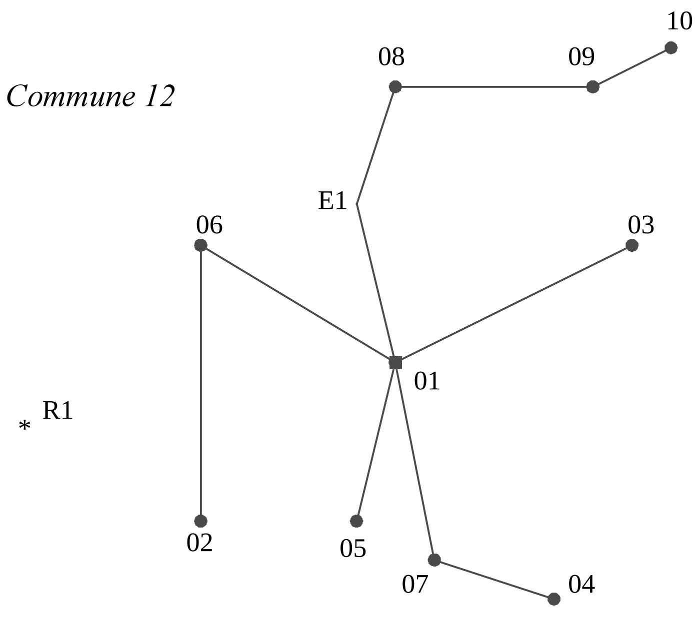
Commune 09



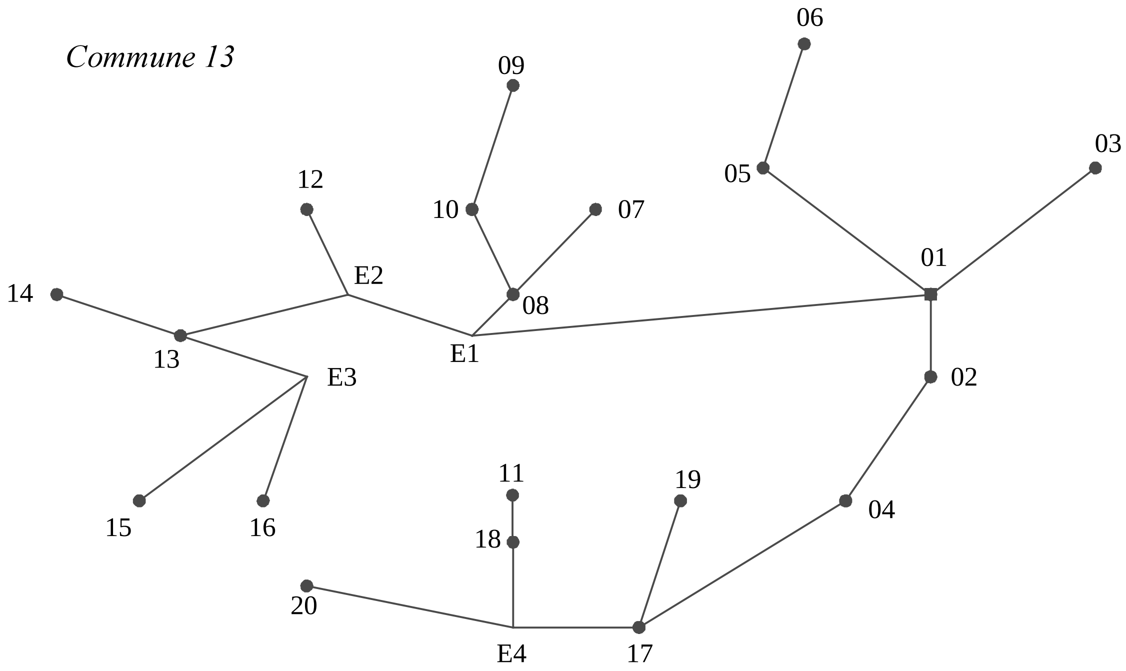
Commune 10



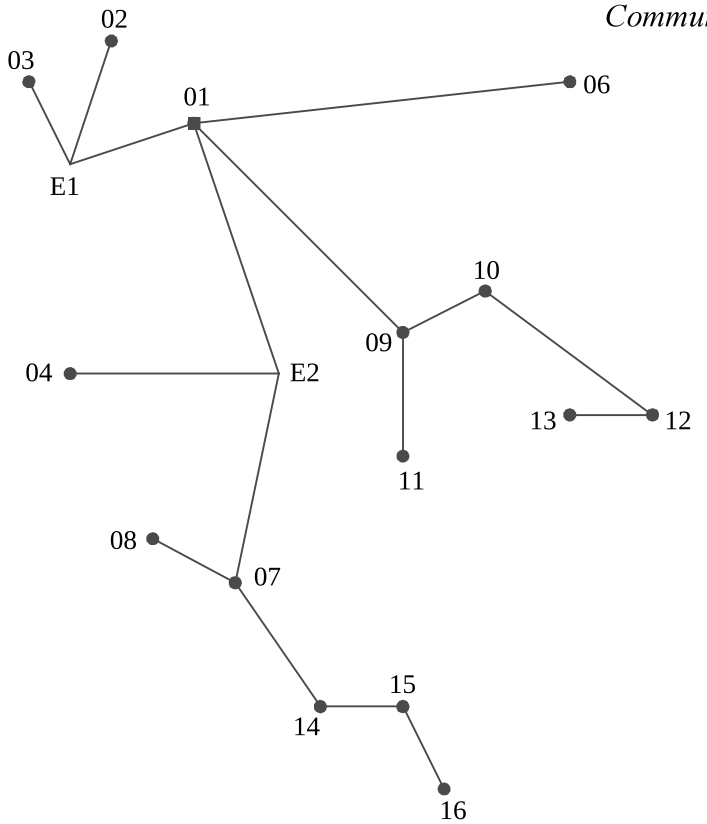

Commune 11
20
E1
09
12
04
05
10
03
13
E3
06
E3
01
02
19
14
07
24
27
15
08
21
16
17
22
33
23
30
37
18
38


Commune 12
10
08
09
E1
06
03
01
* R1
02
05
07
04

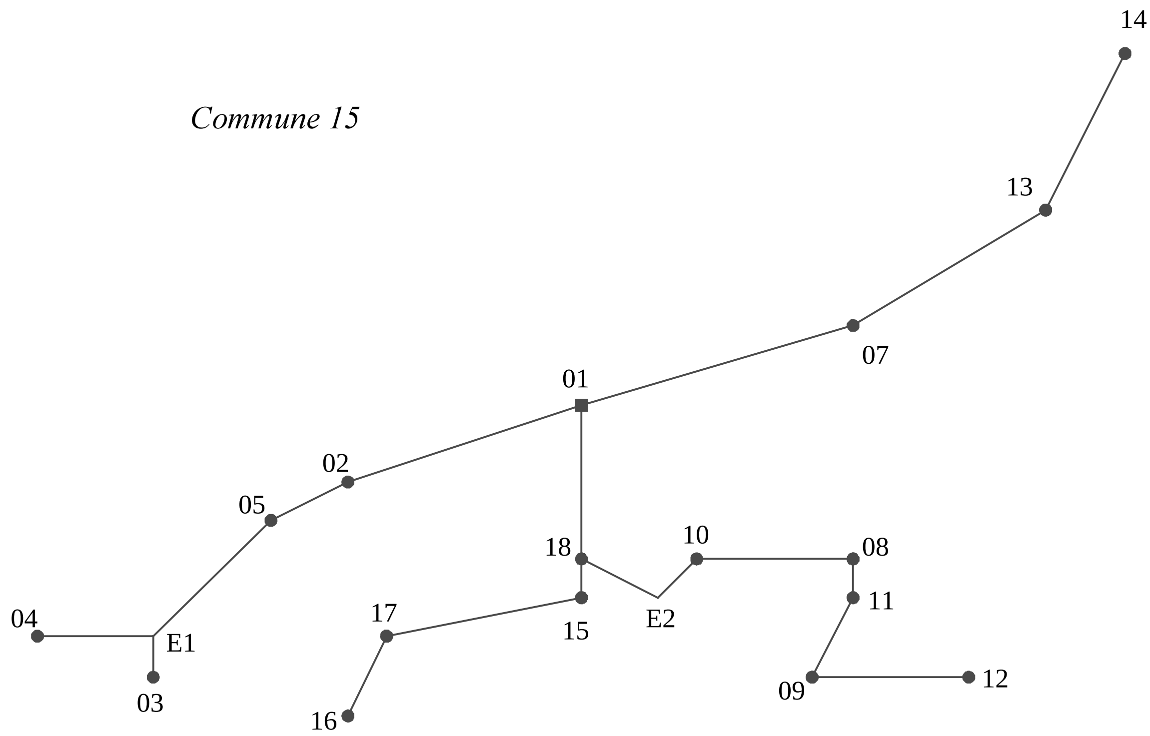
Commune 13



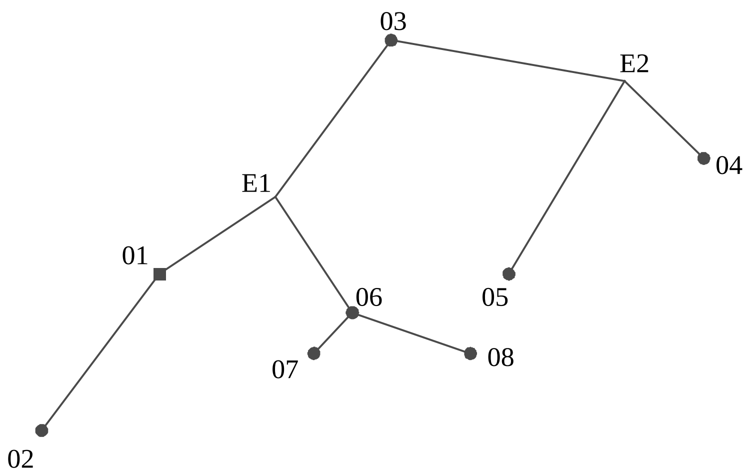
Commune 14



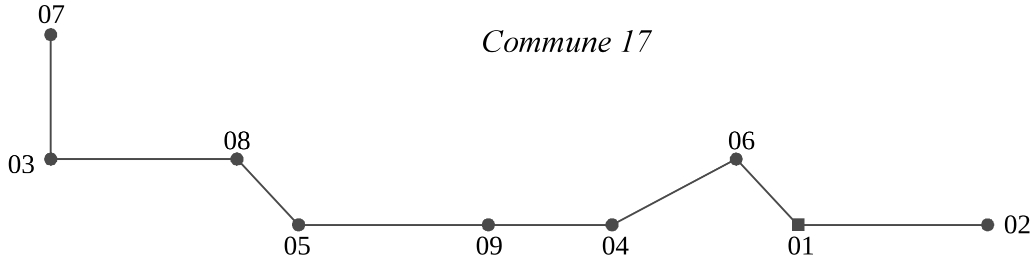
Commune 15



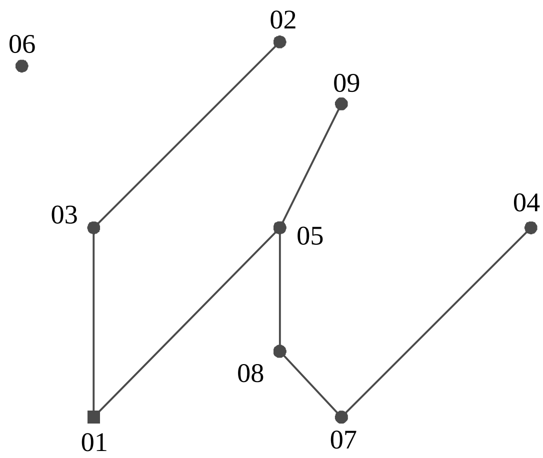
Commune 16



Commune 17



Commune 18



6.4 Special description of some areas

From studying the given population forecasts, you will find that population development trends here are generally the same as in many other areas:

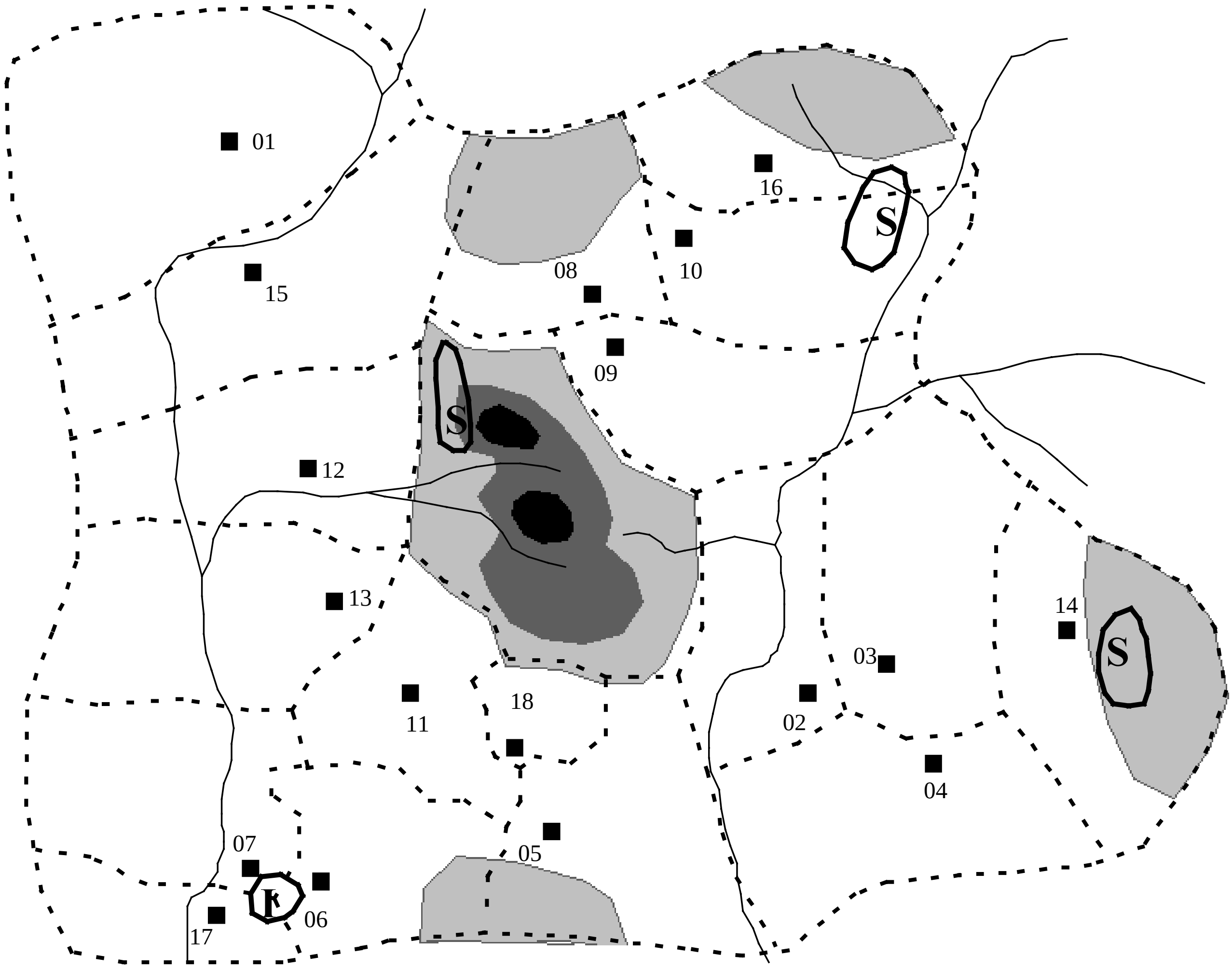
- Quite a few small areas lose population over time and some even become totally depopulated, while in the larger towns, there is a steady increase in population.

- The district centre has played a very central role as administrative centre for the whole district. The trend now is that the biggest towns in the north-east, south-east, and south-west will play a somewhat more important role for the surrounding communes in the future. Some important decisions for future development have already been taken. This may change the category to which they belong for future points of time.

- At three locations, large investments will be made in holiday resorts for both winter sports and summer activities: hotels, cabins, skilifts and many related projects. Some domestic tourists are expected at the resort, but the majority of tourists will probably be foreign.

- A fairly different project, to increase industrialization of an area in the south-west, is also planned. Support to various industries will be provided, including the construction of a large factory to produce telecommunications equipment.

This means, of course, that villages or towns in the areas will be affected. Since the population forecasts given were made before the development plans described here were produced, you might revise the forecasts for such villages or towns but do NOT make any revisions in other cases



Recent Decisions on Development Projects

S = sports and holiday resorts

I = industry

6.5 Waiting List Policy

1. All waiters to be cleared in every five-year development plan; in other words, not one applicant should have to wait more than five years for a telephone;

2. Business waiters to be given priority in communities with over 500 people;

3. In communities with under 500 people, first priority to be given to service centres, i.e., police, health clinics doctors, administrative departments, etc.
   At least two telephone facilities per 100 population if not already provided;
   Second priority given to other applications;

4. Assume no restrictions on investment capital for rural areas;

5. In very small communities with falling populations, waiters are probably absorbed by cessations.

6.6 General ideas on traffic categories

It is generally accepted that small rural locations like villages and country towns are reasonably well suited to the concept of traffic categories.

The underlying idea here is that different places in a given traffic category have reached an equivalent point of development, and that the future is expected to be the same for each of the different places. This would mean that the present and future calling rates are expected to be the same in the different places, and that the future maximum telephone density level will also be the same.

Since we know that this is not necessarily correct, we should use such a rough method with great care, i.e., combine it with individual judgements, and take every possible oppportunity to check performance in individual cases.

6.7 Description of traffic categories

The premises underlying the work of the administration’s expert group are as follows:

- The categories for the different places depend on the kind of economic activity of the populations in the respective areas. Towns with developed industry belong to higher categories (=lower numbers).

- The six categories introduced are connected, to a great extent, to the expected telecommunication development.

- Telephone density in the district centre, for example, may be about 25 lines per 100 inhabitants, while the corresponding value for the villages may be around 10 lines per 100 population.

- The adopted classification concerns the expected development of both subscriber density and calling rates.

6.8 Hypothetical classification of villages

This is the administration's view to the present date; the traffic category is given for each village. However, some data may be old or pure guess-work; such data should be used, therefore, only as the basis for arriving at a better classification.

After some study and discussions, the administration's expert group presented this table for classification of towns and villages:

TC for commune centres	TC for other populated places
1	4
2	4
3	5
4	5
5	5

As you can see, the table shows very strict standardization, since all villages and towns belonging to a particular commune are expected to be in the same category.

Furthermore, no commune centre in this district is supposed to be in category 0.

In reality, of course, different places have different characteristics as to telephone density, development speed, and calling rates.

You should use this table, therefore, as a rough guide when you determine the detailed categories, both for the present situation and for the future points of time.

Data sheet **B**

Village			Cat				N_v-5	L_v-5	N_v 0	L_v 0	ND_v 5	ND_v10	ND_v15	% 5	%10	%15
P01	01	01	1	1	1	1	12680	1200	16220	1360	0	0	0	1.00	1.00	1.00
P01	01	03	4	4	4	4	21	5	24	7	0	0	0	1.00	1.00	1.00
P01	01	04	4	4	4	4	7	2	10	2	0	0	0	1.00	1.00	1.00
P01	01	07	4	4	4	4	3	0	3	0	0	0	0	1.00	1.00	1.00

c, v

Categories for
T = 0, 5, 10, 15

As you can see, the categories are the same for all points of time. This means that no changes in development trends have been foreseen. You must, of course, reconsider the categories during the forecast process, both for different places and for different points of time.

MODIFY **B** *ACCORDING TO YOUR WELL THOUGHT-OUT OPINIONS!*

6.9 General information on densities

The model chosen to forecast the future number of subscribers requires that a saturation limit for telephone penetration (density) be determined first. Therefore, the administration has earlier tried to associate a given density level with a given traffic category. Again, this method is rather "rough" and therefore the forecaster should be careful to make necessary modifications when needed.

6.10 Maximum densities per traffic category

The administration's expert group has worked out the following table which shows what was expected in the future (or what the prevailing policy was at that time), and the assumed standard values for the present situation.

You should use the *DMAX*-values as start values for the future density forecasts (8.1). The present values, ***MD(0)***$_{TC}$, should not be used as an input (you already know the actual values for *T=-5* and *T=0*), but rather as a guide in case you suspect that the given actual values might be somewhat erroneous in some instances!

TC	$MD(0)_{TC}$	$DMAX_{TC}$
1	0.251	0.530
2	0.155	0.428
3	0.161	0.402
4	0.122	0.330
5	0.104	0.274

TC=0 is not included, but an earlier study estimated that the corresponding $DMAX_{TC}$ value was around 0.61.

The future values are stored in the computer, and the data sheet looks like this:

Six categories of subscriber densities

E

0	0.610
1	0.530
2	0.428
3	0.402
4	0.330
5	0.274

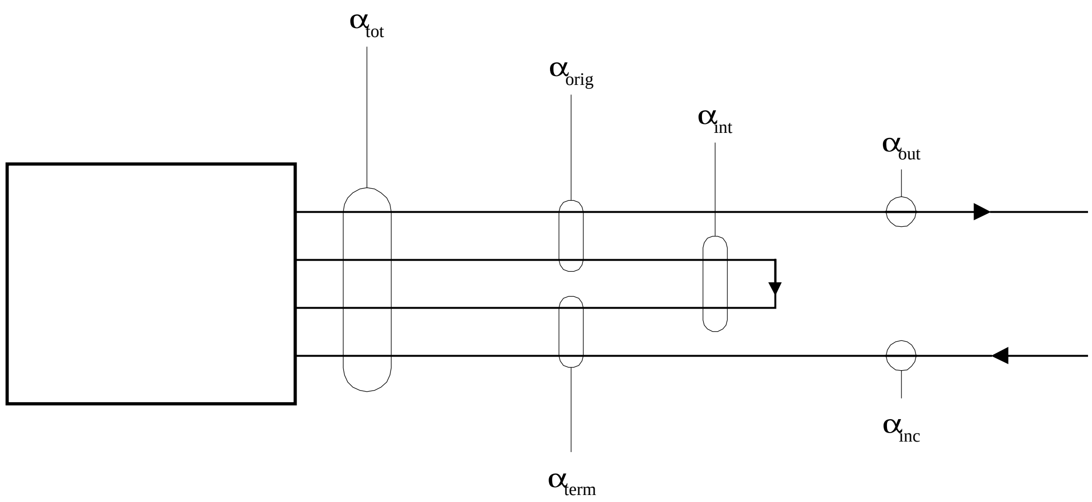
MODIFY **E** *ACCORDING TO YOUR WELL THOUGHT-OUT OPINION!*

6.11 Calling rates per traffic category

The administration's expert group has presented the following table of calling rates per traffic category. Again, these values should be used as a guide when you determine the detailed calling rates.
Note that the values refer to the present time.

TC	$TCR_{TC}(0)$	$PO_{TC}(0)$	$PI_{TC}(0)$
1	0.113	0.478	0.804
2	0.097	0.495	0.720
3	0.090	0.511	0.702
4	0.076	0.526	0.578
5	0.055	0.582	0.506

Generally speaking, "calling rate" means "traffic per subscriber line (=main line)". Correspondences between the three variables used here and some perhaps more well-known parameters are given below:



$$TCR = \alpha_{tot}$$
$$PO = \frac{\alpha_{orig}}{\alpha_{tot}}$$
$$PI = \frac{\alpha_{int}}{\alpha_{tot}}$$

according to the definitions

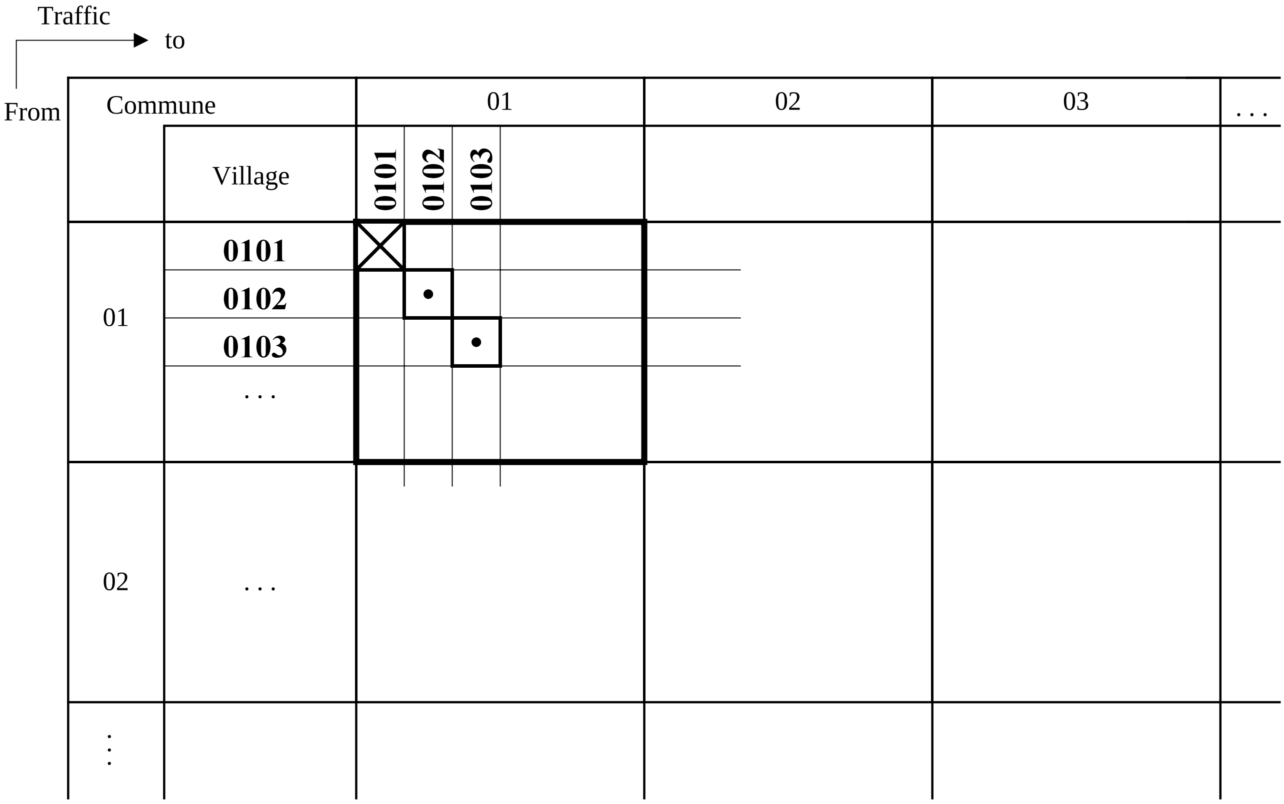
$$\alpha_{tot} = TCR$$
$$\alpha_{orig} = TCR \cdot PO$$
$$\alpha_{term} = TCR \cdot (1 - PO)$$
$$\alpha_{out} = TCR \cdot (PO - PI/2)$$
$$\alpha_{inc} = TCR \cdot (1 - PO - PI/2)$$
$$\alpha_{int} = TCR \cdot PI$$

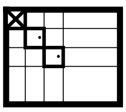
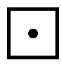
Note that PI or α_{int} in this study refers to internal traffic created both by calling and called subscribers by definition.

In other documents, the definition may be different, e.g., traffic created only by calling subscribers.

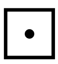
When, for example, you estimate the detailed internal calling rates, remember that the average value for a particular commune, $\boldsymbol{PI_c\ (0)}$, must be lower than the internal commune traffic per subscriber (see 6.2), and that the individual values $\boldsymbol{PI_v\ (0)}$ for small places in that commune must be much lower than the individual value for the commune center, $\boldsymbol{PI_{v=01}(0)}$.

An explanation is found in the figure, below:



 = internal traffic in the commune. (It is, of course, greater than the sum of  and 

 = internal traffic in the commune centre (always village no..01).
(It is usually high or very high.)

 = internal traffic in a village or town. (It is usually low or very low.)

DATA SHEET **(F)** Six categories of calling rates

Cat	TCR	PO	PI	TCR	PO	PI	TCR	PO	PI	TCR	PO	PI
	T = 0			T = 5			T = 10			T = 15		
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	0.113	0.478	0.804	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.097	0.495	0.720	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.090	0.511	0.702	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	0.076	0.526	0.578	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5	0.055	0.582	0.506	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

*MODIFY **F** FOR T=0 ACCORDING TO WELL THOUGHT OUT DECISIONS!*

By the way, do you really think that a village with 10 subscribers has a proportion of internal traffic of about 50%?

6.12 Development of calling rates

The administration's expert group has worked out a standard set of future "saturation levels" for calling rates, i.e., the calling rates they believe will correspond to the "saturation density" levels. Again, reality is more complicated, so you may use these values as guidance when you study the calling rate development in detail.

TC	TCR_{TC} (SAT)
1	0.107
2	0.079
3	0.074
4	0.059
5	0.041

As you see, the calling rates are supposed to drop when the densities approach "saturation"!
What is your view on this matter?

USE YOUR OWN JUDGEMENT TO MODIFY FUTURE CALLING RATES AND STORE YOUR VALUES IN ***F*** *!*

7. Preparatory Checks And Adjustments

7.1 Calling rates per village

As an option, you could calculate values in the following table,either for a commune or for some villages.

Village	Total Calling rate	Proportion of orig. traffic to total traffic	Proportion of internal traffic to total traffic
v	$TCR_v(0)$	$Po_v(0)$	$Pi_v(0)$
0101			
0102			
. . .			
. . .			

$$\left.\begin{array}{l} TCR_V(0) = TCR_{TC}(0) \\ \quad TC = TC_V(0) \\ \\ PO_V(0) = PO_{TC}(0) \\ \quad TC = TC_V(0) \\ \\ PI_V(0) = PI_{TC}(0) \\ \quad TC = TC_V(0) \end{array}\right\} \text{ from 6.8, 6.11}$$

(This table is not generated by the computer.)

7.2 Hypothetical total present traffics per commune

As a result of your assigning values to *TC_v (0)*, *TCR_{TC} (0)*, *PO_{TC} (0)* and *PI_{TC} (0)* , total originating and terminating traffics per commune will be calculated automatically. These calculated values are called hypothetical since the total values are given (see 6.2, data sheet D: A_{iO} (0) or A_{Tj} (0)). You will realise that these “given” values are probably based on measurements and should not under any circumstances be mistaken for “exact” values. Nonetheless, it is still essential that the “hypothetical” values agree reasonably well with the given values since the next step is to make forecasts, and you need a basis on which to make a check! Carry out the check according to the method described under 7.3.

c	AOH_C (0)	ATH_C (0)

$$AOH_C(0) = \sum_{V \in C} \left\{ N_V(0) \cdot TCR_V(0) \cdot PO_V(0) \right\}$$

$$ATH_C(0) = \sum_{V \in C} \left\{ N_V(0) \cdot TCR_V(0) \cdot \left[1 - PO_V(0) \right] \right\}$$

from 6.1, 7.1

The formulas are implemented in the computer program. The results appear on data sheet G:

DATA SHEET (G) :

	C	AOH_C	ATH_C	N_C
P01	1	910.1	987.4	17070
P01	2	379.0	359.4	8415
P01	3	61.1	43.9	1910
P01	4	40.7	29.2	1271

at T = 0

7.3 Total commune traffic check

Compare the hypothetical total commune traffics in 7.2 with the basic data in 6.2:

Is $AOH_C(0) \approx A_{iO}(0)$?
$i = c$

Is $ATH_C(0) \approx A_{Tj}(0)$?
$j = c$

If not, make your own decisions and adjust (change) 6.11 and/or 6.8 (calling rates or village classifications). Then re-calculate 7.1 and 7.2 and repeat the comparison as above.

A question that may arise is: What do we mean by “≈“ in this case?

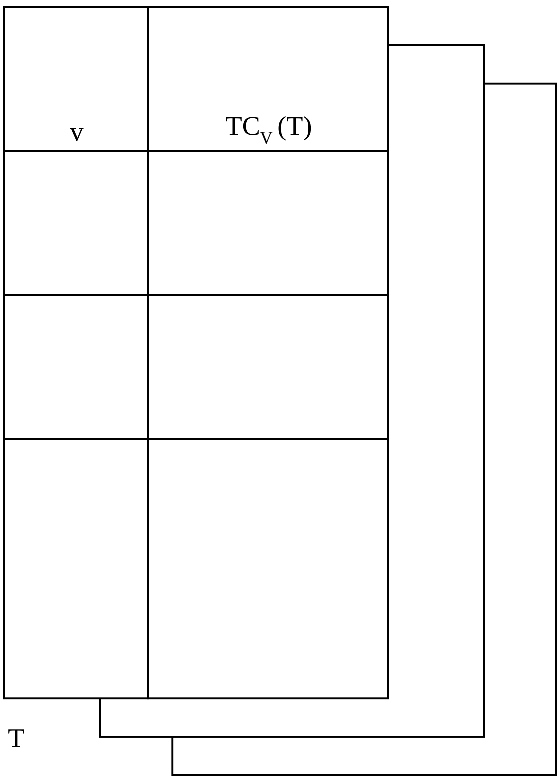
As you know, if we express a confidence interval as a percentage of the mean value, it is generally larger in the case of a small mean value. Perhaps your decisions could be based on a table like the one below:

Traffic	“≈“ coould mean:
Large	< 5% difference
Small	< 10% difference
Very small	< 20% difference

Note that these figures are only presented as an example. You should base your decisions on your own experience.

7.4 Preliminary future village classifications

As start values, the traffic categories you introduced in 6.8 are used.



$$TC_V(T) = TC_V(0)$$

The values are shown in data sheet B. Before you changed them, they looked like this:

B

Village			Cat				N_v-5	L_v-5	N_v 0	L_v 0	ND_v 5	ND_v10	ND_v15	% 5	%10	%15
P01	01	01	1	1	1	1	12680	1200	16220	1360	0	0	0	1.00	1.00	1.00
P01	01	03	4	4	4	4	21	5	24	7	0	0	0	1.00	1.00	1.00
P01	01	04	4	4	4	4	7	2	10	2	0	0	0	1.00	1.00	1.00
P01	01	07	4	4	4	4	3	0	3	0	0	0	0	1.00	1.00	1.00

But you have already changed these values (haven’t you?), so the table may look like this:

B

0	0	1	1
4	4	3	3
3	3	3	3
5	5	5	4

etc.

7.5 Preliminary maximum densities per village

v	$DMAX_V$
0101	
0102	
. . . .	

	from
$DMAX_V = DMAX_{TC}$ $TC = TC_V(T)$	6.10, 7.4

This table is not generated by the computer program.

The computer will find the DMAX-values by combining the table of modified TC-values for the different villages (see 7.4) with the DMAX-values for different TC that you may have also modified (see 6.10)

8. Subscriber Forecast Per Village

The general model is the exponential logistic one which means that the development is supposed to follow a curve which first accelerates, then passes a point of inflection, and finally the development slows down and approaches an asymptote, the "saturation level", or "the maximum density".

8.1 The exponential logistic model

$$D_V = Y_V \cdot DMAX_V$$

$$Y_V = \frac{1}{\left(1 + e^{-C_V(T-T_0)}\right)^{1/M_V}}$$

General subscriber forecast expression

In our case (T = 0)

1. $Y_V(-5) = \frac{N_V(-5) + L_V(-5)}{P_V(-5)} / DMAX_V$

   $Y_V(0) = \frac{N_V(0) + L_V(0)}{P_V(0)} / DMAX_V$

2. $T = 0, \quad Y = Y_V(0)$ — $M_V : M_V = -\frac{\ln 2}{\ln Y_V(0)}$

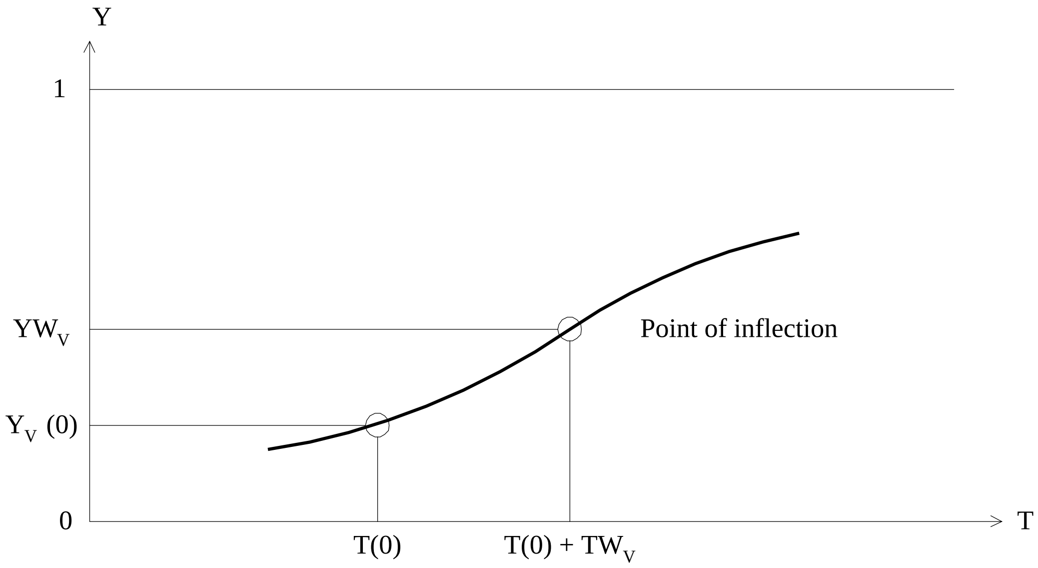
3. $T = -5, \quad Y = Y_V(-5)$ — $C_V : C_V = 1/5 \cdot \ln\left\{(Y_V(-5))^{-M_V} - 1\right\}$

4. $T = 5, 10, 15$ — $Y_V(5), \ Y_V(10), \ Y_V(15)$

5. $TW_V = -\frac{\ln M_V}{C_V}$ — Distance in years from T = 0 to point of inflection

6. $YW_V = \frac{1}{(M_V + 1)^{1/M_V}}$ — Height of curve at point of inflection

7. $D_V(T) = Y_V(T) \cdot DMAX_V(T)$



The computer calculates the future demand for all villages:

B

Village	Cat				N_v-5	L_v-5	N_v 0	L_v 0	ND_v 5	ND_v10	ND_v15	% 5	%10	%15
P01 01 01	1	1	1	1	12680	1200	16220	1360	0	0	0	1.00	1.00	1.00
P01 01 03	4	4	4	4	21	5	24	7	0	0	0	1.00	1.00	1.00
P01 01 04	4	4	4	4	7	2	10	2	0	0	0	1.00	1.00	1.00
P01 01 07	4	4	4	4	3	0	3	0	0	0	0	1.00	1.00	1.00

The logistic function has some valuable properties : it combines the use of historical data with a superimposed, separately estimated saturation level and can therefore work well even with very limited sets of data; it can also utilize more extensive sets of historical data through statistical curve fitting.

A limitation is however that a logistic curve always should be monotonously increasing or decreasing towards the saturation limit.

In this case study, there are historical data only for two points of time. Statistical curve fitting is therefore out of the question, so the logistic curve should preferably pass through both these points. Cases will however occur where historical data do not permit this exact fit.

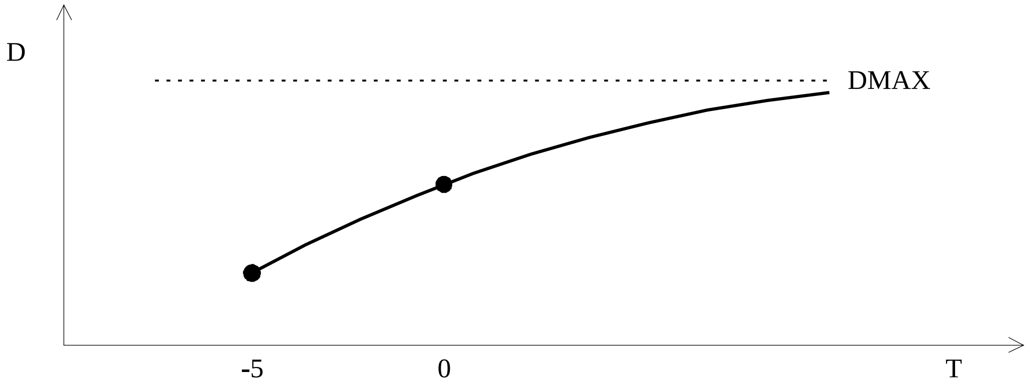
These cases are usually small villages with very few main lines, often combined with a negative population development trend. Under such conditions, data are generally much less stable than otherwise. Density figures can, for example, jump up and down over time.

In these really very few cases, the forecast algorithm will trust the most recent historical data and the saturation level, and will thus adjust the older historical data so as to permit the logistic function to work properly.

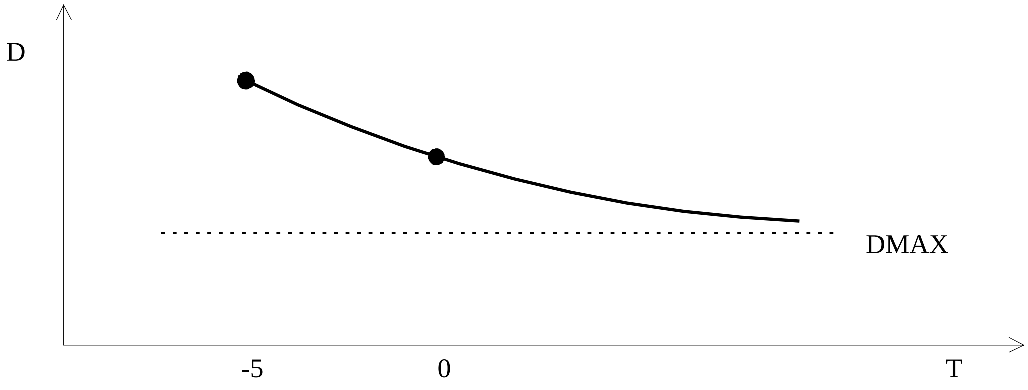
Examples are shown on the next page.

Examples:

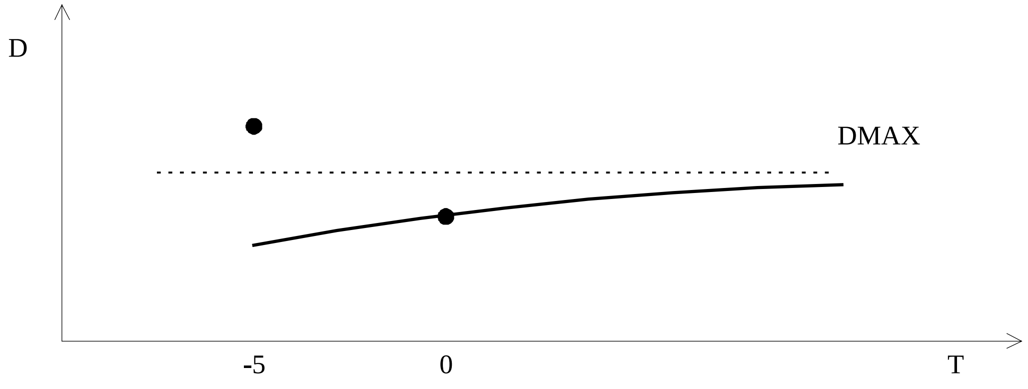
1. The most common case - growth of density both historically and in the future. The logistic function works without adjustment of data.



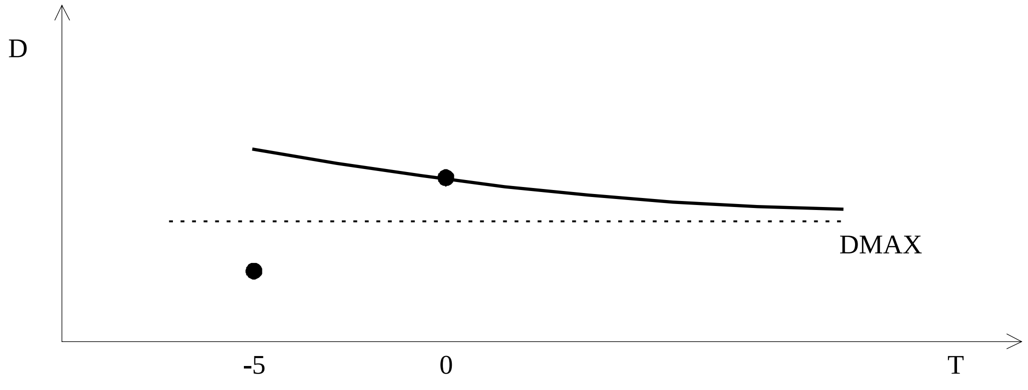
2. A more unusual case - density decreases both historically and in the future. Also this case is calculated without adjustments.



3. Density decreases historically - possibly even crossing the saturation level - but grows again in the future. Here, the older data is adjusted before applying the logistic function.



4. The opposite of (3) above - a historical growth followed by a future decrease. The older data is again adjusted.

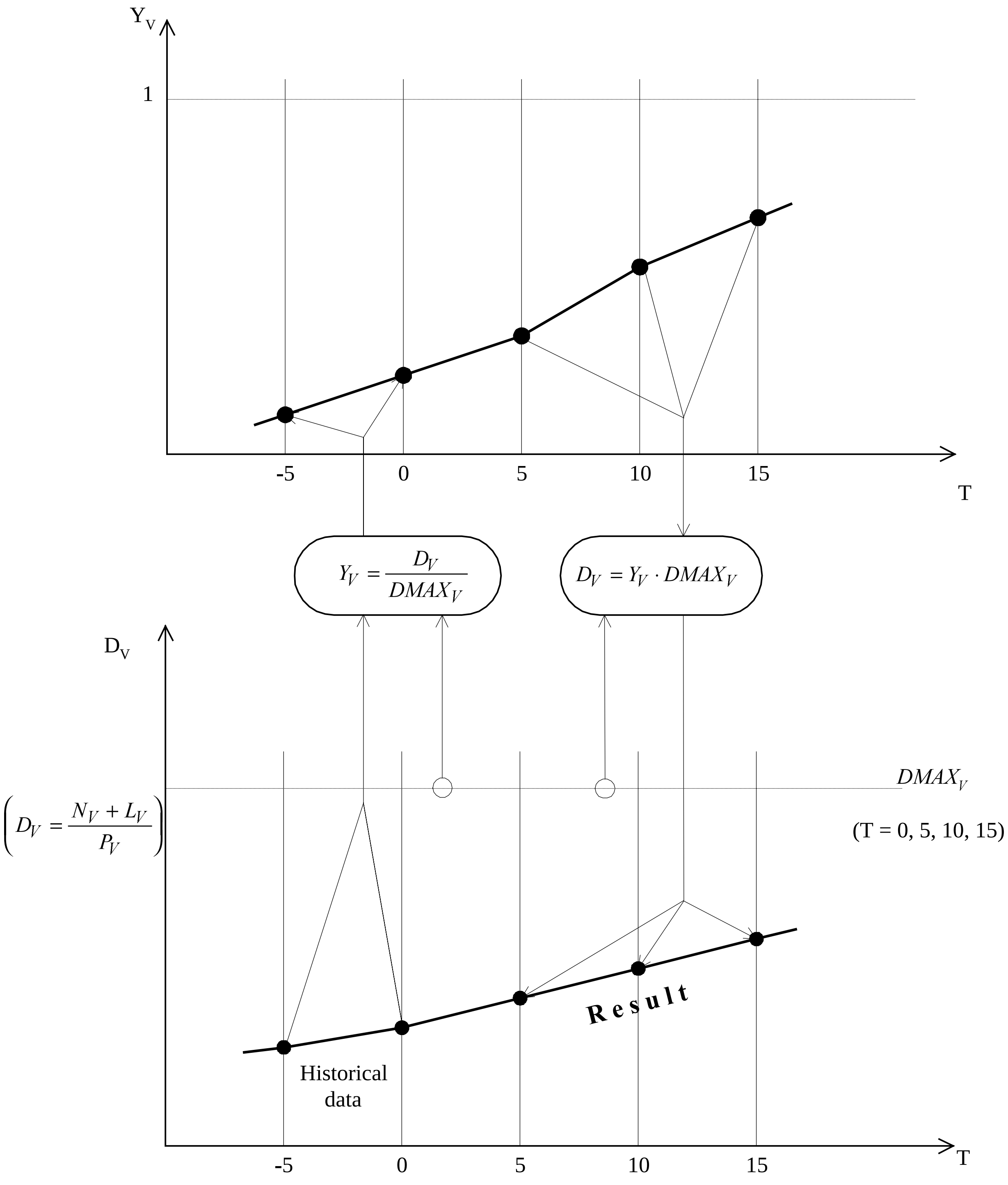


It is essential to know how the computer program deals with different inputs. Two cases are illustrated below:
(a) when a single category applies to all points of time in a village where a forecast is to be made
(b) when the category changes over time.
In the latter case, the computer has to do separate calculations for each point of time for each specified category.

a) Same category TC_v for all points of time

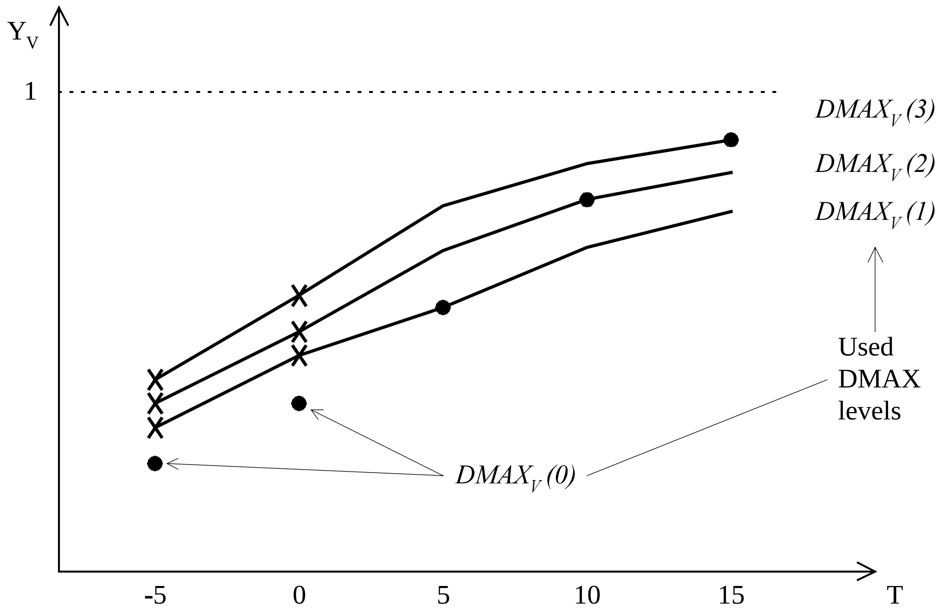
The general, automatic calculation procedure is:

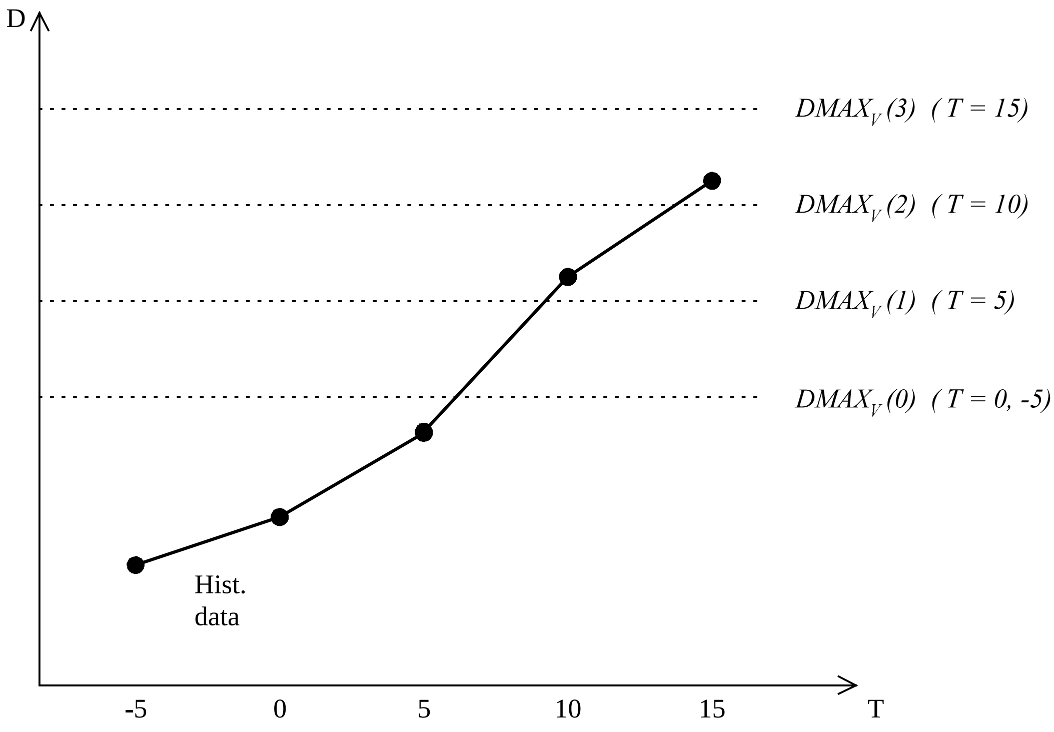
1. Y_v for T = -5, 0 is calculated from D_v , $DMAX_v$
2. Y_v for T = 5, 10, 15 is calculated (= forecast)
3. D_v for T = 5, 10, 15 is calculated from Y_v



b) Different categories TC_V (T) for different points of time T = 0, 5, 10, 15

If category TC_V for a certain village varies with time T, different $DMAX_V$ values will be used for different points of time,T. The automatic calculationprocedure may be illustrated as below:





You may accept or reject the individual forecasts. If you then need to study the behaviour of the logistic function in more detail for some villages, you may do your own detailed calculations for those villages using the following table :

V	M_V	C_V	TW_V	YW_V	Y_V (T)					D_V (T)					$DMAX_V$
					T = - 5	0	5	10	15	T = - 5	0	5	10	15	

A simple version of this kind of study is included in the computer program, so you can study the curve parameters M_V , C_V , etc. on the screen for any particular village.

The results should be scrutinized:

Looking at the table, or at the screen, and consulting 6.3, 6.4, 6.6, and 6.7, focus on:

- The shape of the curve: is the point of inflection reasonable? (We may have passed the point or we may still have an accelerating development.)

- The future densities: perhaps the shape of the curve should be changed or perhaps we should change the absolute density values.

Result of the study:

<u>either</u> accept all values,

<u>or</u> adjust 6.10 and/or 6.8.
If only 6.10 is changed, re-do 8.1.
If 6.8 is changed, return to 7.2.

8.2 Final setting of future village classification

Now we reconsider the future village classifications, 7.4, in the light of the results of the density calculations, 8.1, and, possibly, the changed present village classifications. If, after these adjustments,

$$7.4 \neq 6.8$$

then return to 8.1.

8.3 Future waiting list

After reviewing 6.3, 6.4, and 6.5, use your own individual judgement to determine a vector:

$PN_V\ (T)$

to express what proportion of the total future demand will be connected (not waiting).

Data sheet B shows where you should read in the values:

T

Village	Cat				N_V-5	L_V-5	N_v 0	L_v 0	ND_v 5	ND_v10	ND_v15	% 5	% 10	% 15
P01 01 01	1	1	1	1	12680	1200	16220	1360	0	0	0	1.00	1.00	1.00
P01 01 03	4	4	4	4	21	5	24	7	0	0	0	1.00	1.00	1.00
P01 01 04	4	4	4	4	7	2	10	2	0	0	0	1.00	1.00	1.00
P01 01 07	4	4	4	4	3	0	3	0	0	0	0	1.00	1.00	1.00

$PN_v\,(T)$

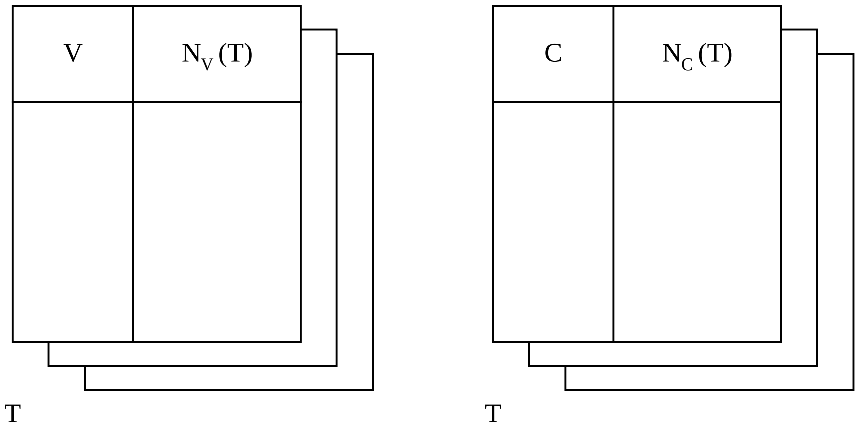
B

The values shown correspond to 100% connected lines, i.e., no waiting list at all. After your revision, the table may look like this :

B

% 5	% 10	% 15
0.90	0.95	1.00
1.00	1.00	1.00
0.85	0.85	0.90
0.95	1.00	1.00
. . .		
. . .		
. . .		

8.4 Final forecast



$$N_V(T) = P_V(T) \cdot D_V(T) \cdot PN_V(T)$$
$$N_C(T) = \sum_{V \in C} N_V(T)$$

The table, above left, is not generated by the computer program.
The table, above right, looks like this on data sheet G :

G

Com	AOc	ATc	Nc	Pop at T = 5
P01 1	0.0	0.	0	0
P01 2	0.0	0.0	0	0
P01 3	0.0	0.0	0	0
P01 4	0.0	0.0	0	0

9. **Traffic Forecasts**

9.1 Future calling rates per traffic category

Use your individual judgement to make decisions concerning the future calling rates after considering basic data and information and the results of the calculations you have already made.
See 6.3, 6.4, 6.6, 6.7, 6.11, 6.12, and 8.1.

Traffic category TC	Total Calling rate (orig.+ term) $TCR_{TC}\ (T)$	Proportion orig. traffic of total traf. $PO_{TC}\ (T)$	Proportion internal traffic of total traffic $PI_{TC}\ (T)$
0			
1			
. . .			
5			

T

After this, you should read in the values to the computer. The data sheet looks like this:

F

6 Categories of calling rates

Cat	TCR	PO	PI	TCR	PO	PI	TCR	PO	PI	TCR	PO	PI
		T = 0			T = 5			T = 10			T = 15	
0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	0.113	0.478	0.804	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.097	0.495	0.720	0.	0.	0.	0.	0.	0.	0.	0.	0.
3	0.090	0.511	0.702	0.	0.	0.	0.	0.	0.	0.	0.	0.
4	0.076	0.526	0.578	0.	0.	0.	0.	0.	0.	0.	0.	0.
5	0.055	0.582	0.506	0.	0.	0.	0.	0.	0.	0.	0.	0.

This is file RURCARATE.DAT, and you should set the parameters for T=5, T=10, and T=15.

9.2 Future calling rates per village

Village v	Total Calling rate $TCR_V(T)$	Proportion orig. traffic of total traf. $PO_V(T)$	Proportion internal traffic of total traf. $PI_V(T)$

T

$$\left.\begin{aligned} TCR_V(T) &= TCR_{TC}(T) \\ TC &= TC_V(T) \\[1ex] PO_V(T) &= PO_{TC}(T) \\ TC &= TC_V(T) \\[1ex] PI_V(T) &= PI_{TC}(T) \\ TC &= TC_V(T) \end{aligned}\right\} \quad \text{from 7.4, 9.1}$$

This table is not generated by the computer program.

9.3 Forecast of total commune traffics

i \ j	1	2	- - -	Σ	LD	Σ
1						A_{iO} (T)
2						
- - -						
Σ						
LD					0	- - -
Σ		A_{Tj} (T)			- - -	A_0 (T) / A_T (T)

$$A_{iO}(T) = \sum_V \left(N_V(T) \cdot TCR_V(T) \cdot PO_V(T)\right) \qquad V \in \text{ commune } i$$

$$A_{Tj}(T) = \sum_V \left(N_V(T) \cdot TCR_V(T) \cdot \left(1 - PO_V(T)\right)\right) \qquad V \in \text{ commune } i$$

$$\left.\begin{array}{l} A_O(T) = \sum_i A_{iO}(T) \\ A_T(T) = \sum_j A_{Tj}(T) \end{array}\right\} A_O(T) \neq A_T(T)$$

The calculation formulas are generated by the computer, and the values are presented in data sheet G:

G

Com		AOc	ATc	Nc	Pop at T = 5
P01	1	1169.5	1360.6	22385	73460
P01	2	483.0	458.0	10727	45630
P01	3	95.2	77.0	2683	13600
P01	4	62.3	50.6	1746	11220

Relying on your own judgement, you may adjust the values.

Note that this was now the first step in the process of creating the future traffic matrix, so except for these total originating and terminating traffics per commune, the matrix is empty so far.

9.4 Forecast of LD-traffics for communes

i \ j	1	2	- - -	Σ	LD	Σ
1						
2					A_{iL} (T)	
- - -						
Σ					A_{DL} (T)	
LD		A_{Lj} (T)	A_{LD} (T)		0	- - -
Σ					- - -	

You may choose any of the methods below:

Alternative (a): Proportional to total traffics (present and future)

$$A_{iL}(T) = A_{iL}(0) \cdot \frac{A_{iO}(T)}{A_{iO}(0)}$$

$$A_{Lj}(T) = A_{Lj}(0) \cdot \frac{A_{Tj}(T)}{A_{Tj}(0)}$$

Alternative (b): Decide the LD-calling rates per subscriber in the different TC, and multiply them by the subscriber forecast for the corresponding villages, and then aggregate them into commune values.

Alternative (c): Other methods, or on a one-by-one basis

$$A_{DL}(T) = \sum_i A_{iL}(T)$$

$$A_{LD}(T) = \sum_j A_{Lj}(T)$$

No calculation formulas for the LD-traffic forecasts are implemented so you have to do the job yourself. When you have finished, you should read in the values to the computer; they will appear in data sheet I (see 9.8).

This was the second step in the process of creating the future traffic matrix, so except for total originating and terminating traffics per commune and for LD-traffics, the matrix is still empty.

9.5 Total intra-district traffics

i \ j	1	2	- - -	Σ	LD	Σ
1						
2				$A_{iD}(T)$		
- - -						
Σ		$A_{Dj}(T)$		$A_{DD}(T)$		
LD					0	- - -
Σ					- - -	

$$A'_{iD}(T) = A_{iO}(T) - A_{iL}(T) \qquad A''_{Dj}(T) = A_{Tj}(T) - A_{Lj}(T)$$

$$A'_{DD}(T) = \sum_i A'_{iD}(T) \qquad A''_{DD}(T) = \sum_j A''_{Dj}(T)$$

$$A_{DD}(T) = \frac{A'_{DD}(T) + A''_{DD}(T)}{2}$$

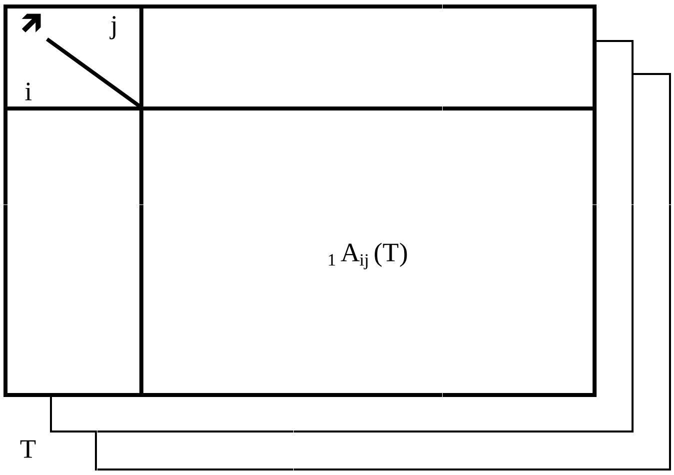
$$A_{iD}(T) = A'_{iD}(T) \cdot \frac{A_{DD}(T)}{A'_{DD}(T)} \qquad A_{D}\ (T) = A''_{D}\ (T) \cdot \frac{A_{DD}(T)}{A''_{DD}(T)}$$

The formulas are implemented in the computer, but the results are not printed. This was the <u>third</u> step in the process of creating the future traffic matrix. What happened was that,

a) total intra-district traffics were calculated by subtracting LD-traffics from total originating and terminating traffics per commune;
b) the two classes of intra-district traffics - originating and terminating traffics - were balanced against each other so their sums would agree.

The rest of the matrix - inter-commune traffics - is still empty.

9.6 <u>Preliminary inter-commune traffics</u>



The purpose here is to create a relation matrix which can be used with the total traffics

Alternative (a) : we use Affinity Factors (see 9.7 for explanation) :

$$ {}_{1}A_{ij}(T) = F_{ij}(T) \cdot \frac{A_{iD}(T) \cdot A_{Dj}(T)}{A_{DD}(T)} $$

Alternative (b) : we use the Weighted Growth model :

$$ {}_{1}A_{ij}(T) = A_{ij}(0) \cdot \frac{W_i \cdot G_j + W_j \cdot G_i}{W_i + W_j} $$

$$ G_i = \frac{N_i(T)}{N_i(0)} \quad ; \quad G_j = \frac{N_j(T)}{N_j(0)} $$

Choose between :

Rapp 1 : $W_i = N_i(T)$ $\qquad W_j = N_j(T)$

Rapp 2 : $W_i = \left(N_i(T)\right)^2$ $\qquad W_j = \left(N_j(T)\right)^2$

APO : $W_i = \frac{N_i(0) + N_i(T)}{2}$ $\qquad W_j = \frac{N_j(0) + N_j(T)}{2}$

"Rapp 1" is based on the following assumption : "The traffic from <u>one</u> subscriber in area **i** to <u>all</u> subscribers in area **j** <u>and</u> the traffic from <u>all</u> subscribers in area **i** to <u>one</u> subscriber in area **j** should not change over time".

"Rapp 2" : "The sum of the square of the change over time in traffic per subscriber in area **i** and the same in area **j** is minimised".

"APO" could hardly be expressed in a similar manner.

Alternative (c) : Another method.

All the formulas shown above are implemented in the computer, but the results are not printed.

9.7 Affinity factors for inter-commune traffics

Definition and explanation

If, for the present point of time, we know only total traffics, $A_{iD}(0)$, $A_{Dj}(0)$, $A_{DD}(0)$:

↗		j	. . .	Σ
i		?		$A_{iD}(0)$
. . .				
Σ		$A_{Dj}(0)$		$A_{DD}(0)$

(Present total originating and terminating traffics per commune)

then we could perhaps calculate hypothetical point-to-point traffics $A_{ij}(0)^H$ by distributing each known originating traffic $A_{iD}(0)$ in proportion to the total terminating traffics $A_{Dj}(0)$:

$$A_{ij}(0)^H = A_{iD} \cdot \frac{A_{Dj}(0)}{A_{DD}(0)}$$

Result :

↗		j	. . .	Σ
i		$A_{ij}(0)^H$		$A_{iD}(0)$
. . .				
Σ		$A_{Dj}(0)$		$A_{DD}(0)$

(Hypothetical point-to-point traffics, based on proportional distribution of total traffics)

However, we happen to know the point-to-point traffics :

↗		j	. . .	Σ
i		$A_{ij}(0)$		$A_{iD}(0)$
. . .				
Σ		$A_{Dj}(0)$		$A_{DD}(0)$

(Known point-to-point traffics)

The ratios beetwen <u>known</u> and <u>hypothetical</u> point-to-point traffics are called <u>affinity factors</u>, F:

$$F_{ij}(0) = \frac{A_{ij}(0)}{A_{ij}(0)^H} = \frac{A_{ij}(0)}{A_{iD} \cdot \frac{A_{Dj}(0)}{A_{DD}(0)}} = \frac{A_{DD}(0) \cdot A_{ij}(0)}{A_{iD}(0) \cdot A_{Dj}(0)}$$

Typically, the affinity factors look like this :

↗		j	- -
i	1.25	0.83	- -
	0.91	1.40	- -
. . .	. . .	. . .	. . .

(Affinity factors demonstrate how relatively strong or weak the traffic interests are between different points)

We shall now use these factors to estimate <u>future point-to-point</u> traffics from predicted future <u>total</u> traffics.

One question that arises is: Will F remain the same in the future, i.e., will $F_{ij}(T) = F_{ij}(0)$? If you believe F will change, then you must feed in adjusted values to the computer!

The program will then:

1. Calculate <u>hypothetical</u> point-to-point traffics for time T:
   $$A_{ij}(T)^H = A_{iD}(T) \cdot \frac{A_{Dj}(T)}{A_{DD}(T)}$$

2. Multiply these hypothetical values by F:
   $$A_{ij}(T) = A_{ij}(T)^H \cdot F_{ij}(T)$$

   and $A_{ij}(T)$ is the final result!

<u>WORK PROCEDURE</u>

i ↗ j	
	$F_{ij}(0)$ or $F_{ij}(T)$

$$F_{ij}(0) = \frac{A_{DD}(0) \cdot A_{ij}(0)}{A_{iD}(0) \cdot A_{Dj}(0)}$$ (automatically calculated values)

$$F_{ij}(0) \rightarrow F_{ij}(T)$$ (possible adjustment through individual judgement)

Should you choose to calculate the reference matrix of preliminary point-to-point traffics (inter-commune traffics) using affinity factors, you must first calculate the present affinities according to the formula above, and then <u>adjust them</u> according to expected future changes (e.g., particular areas are expected to develop faster than before, or the proportion of business subscribers will increase). Generally, in such areas, both the <u>internal</u> traffic and the traffic <u>between</u> the areas will increase. This corresponds to increased affinity factors.

In areas with decreasing activities and population, the incoming traffic per subscriber will often decrease, while the outgoing traffic per subscriber may very well increase. Internal traffic generally then decreases.

The formula is implemented in the computer. The corresponding data sheet should look like this:

Affinity factors for year 0

1	2.28	0.14	0.16	0.18	0.17	0.15	0.18	0.14	0.14	0.15
	0.14	0.19	0.17	0.18	0.18	0.18	0.19	0.23		
2	0.26	4.43	0.30	0.34	0.31	0.28	0.36	0.27	0.27	0.28
	0.27	0.37	0.33	0.33	0.34	0.33	0.37	0.27		
3	0.38	0.40	19.91	0.51	0.46	0.42	0.46	0.41	0.41	0.41
	0.41	0.63	0.46	0.52	0.53	0.48	0.56	1.36		
4	0.50	0.51	0.53	34.13	0.64	0.55	0.58	0.51	0.53	0.51
	0.53	0.59	0.57	0.68	0.69	0.60	0.70	0.00		
. . .	. . .	. . .								

H

If you want to change the affinity factors for year 5, 10, 15, then you must do this by storing new values for these points of time :

Affinity factors for year 5

1
2 (Type your values here!)
.. .
etc.

9.8 Future traffic matrix for communes

i \ j	1	2	- - -	Σ	LD	Σ
1		A_{ij} (T)		A_{iD} (T)	A_{iL} (T)	A_{iO} (T)
2						
- - -						
Σ		A_{Dj} (T)		A_{DD} (T)	A_{DL} (T)	A_{DO} (T)
LD		A_{Lj} (T)		A_{LD} (T)	0	- - -
Σ		A_{Tj} (T)		A_{TD} (T)	- - -	A_0 (T) / A_T (T)

T

Reconciliation, using Kruithof's "Double Factor Method" :

Step 1)
$$_2A_{ij}(T) = \frac{_1A_{ij}(T)}{\sum_j {_1A_{ij}(T)}} \cdot A_{iD}(T)$$

Step 2)
$$_3A_{ij}(T) = \frac{_2A_{ij}(T)}{\sum_i {_2A_{ij}(T)}} \cdot A_{Dj}(T)$$

Step 3)
$$_4A_{ij}(T) = \frac{_3A_{ij}(T)}{\sum_j {_3A_{ij}(T)}} \cdot A_{iD}(T)$$
etc.

Note that one stable decimal is more than adequate!
(Alternatively, the reconciliation could be made for the traffic increase instead of for the total future traffics.)

After that, $A_{ij}(T)$ are rounded off to 1 decimal, and:

$$A_{iD}(T) = \sum_i A_{ij}(T)$$

$$A_{Dj}(T) = \sum_j A_{ij}(T)$$

$$A_{DD}(T) = \sum_i A_{iD}(T) = \sum_j A_{Dj}(T)$$

are calculated.

LD-traffics were calculated before, so now we calculate:

$$A_{iO}(T) = A_{iD}(T) + A_{iL}(T)$$

$$A_{Tj}(T) = A_{Dj}(T) + A_{Lj}(T)$$

$$A_{DO}(T) = \sum_i A_{iO}(T)$$

$$A_{TD}(T) = \sum_j A_{Tj}(T)$$

The calculation formulas form part of the computer program, and the results appear in data sheet I:

DATA SHEET I :

A_{ij} (T) ***A_{iL} (T)***

Inter-commune and LD traffics for time 5

I

983.4	20.1	4.7	3.5	2.2	13.6	1.8	12.4	11.1	6.9	
11.2	2.2	3.4	5.2	5.4	3.7	4.1	0.4	75.1		**i = 1**
52.3	317.6	4.3	3.3	2.0	13.1	1.8	11.1	9.5	6.3	
10.1	2.1	3.2	4.6	4.9	3.4	3.8	0.2	29.7		**i = 2**
16.2	5.9	48.7	0.8	0.5	4.1	0.4	2.9	2.0	1.3	
2.6	0.6	0.6	1.1	1.2	0.8	0.7	0.2	4.8		**i = 3**
11.6	4.2	0.7	31.1	0.4	3.0	0.3	1.9	1.4	0.9	
1.9	0.3	0.4	0.7	0.9	0.5	0.5	0.0	1.5		**i = 4**

A_{iL} (T)

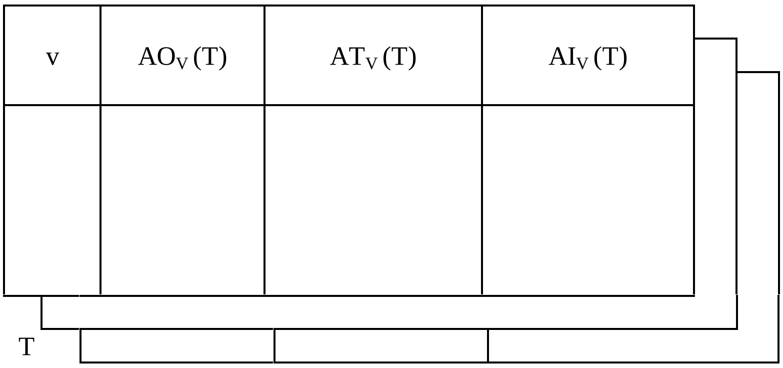
9.9 Present traffics per village

v	$AO_V(0)$	$AT_V(0)$	$AI_V(0)$

$$AO_V(0) = N_V(0) \cdot TCR_V(0) \cdot PO_V(0)$$
$$AT_V(0) = N_V(0) \cdot TCR_V(0) \cdot (1 - PO_V(0))$$
$$AI_V(0) = N_V(0) \cdot TCR_V(0) \cdot PI_V(0)/2$$

The formulas are implemented in the computer program. The values are printed together with the future values (see 9.10).

9.10 Future traffics per village



$$AO_V(T) = N_V(T) \cdot TCR_V(T) \cdot PO_V(T)$$
$$AT_V(T) = N_V(T) \cdot TCR_V(T) \cdot (1 - PO_V(T))$$
$$AI_V(T) = N_V(T) \cdot TCR_V(T) \cdot PI_V(T)/2$$

Results for 9.9 and 9.10:

Data sheet **J**

	T = 0			5			10			15		
P010101	858.0	1007.3	746.1	1125.5	l321.2	)78.7	1320.7	.550.4	.148.4	1498.6	1759.2	1303.1
P010103	1.0	0.9	0.4	1.4	1.3	0.5	1.5	1.4	0.6	1.6	1.4	0.6
P010107	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0
P010108	0.7	0.6	0.3	1.0	0.9	0.4	1.1	1.0	0.4	1.2	1.1	0.5
P010109	4.4	4.0	1.7	6.6	5.9	2.5	7.7	6.9	2.9	8.5	7.7	3.2

Internal traffic $AI_V(T)$

C, V — Terminating traffic $AT_V(T)$

Originating traffic $AO_V(T)$

The real forecasts are now nearly finished. One thing remains,however: to check whether or not the forecasted village traffics agree with the corresponding internal traffics in the forecasted inter-commune traffic matrices.

The reason we make such a check is that since each of these two forecasts has been made independently, they could very well be inconsistent. The outgoing and incoming village traffics probably include rather small quantitites of long distance traffic and traffic with other communes, so the major part of the traffic must be with the commune centre and with other villages in the same commune.

Consequently you should make the following check for each commune separately:

$$AI_{01} + \sum_{V>01} AI_V < A_{ii}$$
$$AI_{01} + \sum_{V>01} AO_V + \sum_{V>01} AT_V + \sum_{V>01} AI_V > A_{ii}$$

where

AI_{01} = internal traffic for village 01 (the commune centre)

$\sum_{V>01} AI_V$ = internal traffic for the other villages

$\sum_{V>01} AO_V$ = originating traffic for the other villages

$\sum_{V>01} AT_V$ = terminating traffic for the other villages

A_{ii} = internal traffic for the whole commune

The use of these **in**equalities to check A_{ii} indicates a certain degree of **un**certainty. To understand why, let us look at the complete inter-village traffic matrix for one particular commune:

↗	Commune centre (v = 01)	Other Villages (v > 01)	Outside commune (x)	Σ
Commune centre (v = 01)	AI_{01}	$\sum_{V>01} A_{01\to V}$		
Other Villages (v > 01)	$\sum_{V>01} A_{V\to 01}$	$\sum_{V>0} AI_V$ / $\sum_{V>01} A_{V\to V}$	$\sum_{V>01} A_{V\to X}$	$\sum_{V>01} AO_V$
Outside commune (x)		$\sum_{V>01} A_{X\to V}$	…	
Σ		$\sum_{V>01} AT_V$		

To get an exact picture of the traffic flow in the commune, we would have to know all quantities shown in the matrix. However, the shaded rectangles are not known to us. All the other values in the matrix are forecasted as shown in the list of villages (originating, terminating, and internal traffics). Only one value, the <u>total</u> internal commune traffic, A_{ii}, is taken from the traffic matrix between communes.

The boldly framed area in the matrix represents A_{ii} .

The matrix shown above can now be used to define two other equations containing both known and unknown quantitites:

$$AI_{01} + \sum_{V>01} AI_V = A_{ii} - \left(\sum_{V>01} A_{01\to V} + \sum_{V>01} A_{V\to 01} + \sum_{V>01} A_{V\to V} \right)$$

$$AI_{01} + \sum_{V>01} AO_V + \sum_{V>01} AT_V - \sum_{V>01} AI_V = A_{ii} + \left(\sum_{V>01} A_{V\to X} + \sum_{V>01} A_{X\to V} + \sum_{V>01} A_{V\to V} \right)$$

The unknown quantities appear inside brackets ( ).

If we look a bit closer, we find that they are probably very small compared to the known quantities. Therefore we can remove them from the equations, but at the same time, of course, we must change the equality signs (=) to inequality signs (< or >).

A_{ii} ,internal traffic for the whole commune, is to be taken from the forecasted inter-commune traffic matrix; the other quantities come from the village traffic forecast.

The limiting quantities:

$$AI_{01} + \sum_{V>01} AI_V$$

and

$$AI_{01} + \sum_{V>01} AO_V + \sum_{V>01} AT_V - \sum_{V>01} AI_V$$

are calculated automatically and presented in table form for all communes and for all points of time, T=0, 5, 10, 15.

You should make sure that A_{ii} (the diagonal values in the traffic matrices) are between the two limiting quantities.

Should the inequalities, shown above, <u>not</u> be confirmed by the checking procedure, then a revision must be made.

The first quantity that would then need to be considered is AI_{01} in the village traffic forecast.

<u>Check table</u>

Sum of internal village traffics per commune:

Commune	T = 0		T = 5		T = 10		T = 15	
C0101	748.9	778.9	913.5	950.8	- - -.-	- - -.-	- - -.-	- - -.-
C0102	- - -.-	- - -.-	- - -.-	- - -.-	- - -.-	- - -.-	- - -.-	- - -.-
C0103	- - -.-	- - -.-	- - -.-	- - -.-	- - -.-	- - -.-	- - -.-	- - -.-

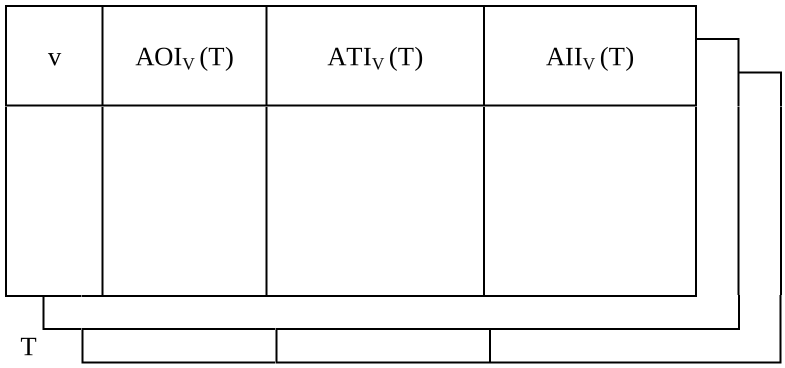
$$AI_{01} + \sum_{V>01} AO_V + \sum_{V>01} AT_V - \sum_{V>01} AI_V$$ (second T = 0 column)

$$AI_{01} + \sum_{V>01} AI_V$$ (first T = 0 column)

9.11 Future village traffics (if intelligent concentrators are used)

In our workshop case study, intelligent concentrators are not considered, and therefore this sub-section does not apply.

Intelligent concentrators (remote subscriber units) can handle internal traffic themselves without using the routes to the commune centres. Therefore, should you decide that such concentrators will be used in certain villages, you have to remove the internal traffics from the village traffic tables.



$$AOI_V(T) = AO_V(T) - AI_V(T)$$
$$ATI_V(T) = AT_V(T) - AI_V(T)$$
$$AII_V(T) = 0$$

for the corresponding v-values.

For other v-values:

$$AOI_V(T) = AO_V(T)$$
$$ATI_V(T) = AT_V(T)$$
$$AII_V(T) = AI_V(T)$$

9.12 Final future traffic matrix for communes if intelligent concentrators are used

In our workshop case study, this sub-section does not apply.

Internal village traffics that can be handled by intelligent concentrators are removed from the matrix:

i \ j	1	2	- - -	Σ	LD	Σ
1		AF_{ij} (T)		AF_{iD} (T)	AF_{iL} (T)	AF_{iO} (T)
2						
- - -						
Σ		AF_{Dj} (T)		AF_{DD} (T)	AF_{DL} (T)	AF_{DO} (T)
LD		AF_{Lj} (T)		AF_{LD} (T)	0	- - -
Σ		AF_{Tj} (T)		AF_{TD} (T)	- - -	AF_0 (T) / AF_T (T)

T

$$AF_{ii}(T) = A_{ii}(T) - \sum_{\substack{V \in C \\ (c=i)}} \left(AI_V(T) - AII_V(T) \right)$$

$$AF_{ij}(T) = A_{ij}(T) \quad i \neq j$$

$$AF_{iD}(T) = \sum_i AF_{ij}(T)$$

$$AF_{Dj}(T) = \sum_j AF_{ij}(T)$$

$$AF_{iL}(T) = A_{iL}(T)$$

$$AF_{Lj}(T) = A_{Lj}(T)$$

$$AF_{DL}(T) = A_{DL}(T)$$

$$AF_{LD}(T) = A_{LD}(T)$$

$$AF_{iO}(T) = AF_{iD}(T) + AF_{iL}(T)$$

$$AF_{Tj}(T) = AF_{Dj}(T) + AF_{Lj}(T)$$

$$AF_{DO}(T) = \sum_i AF_{iO}(T)$$

$$AF_{TD}(T) = \sum_j AF_{Tj}(T)$$

10. **Final Forecasts**

The required final forecasts are:

Subscriber forecast per village: 8.4
Traffic forecast per village: 9.10 (or 9.11*)
Traffic forecast for communes: 9.8 (or 9.12*)

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* In case intelligent concentrators are considered.
In our little workshop case study, they are not.
Therefore, forecasts to be reported are: 8.4, 9.10, 9.8.