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CONSTRUCTING CRITERIA "POPULATION"
FOR THE COMPARISON OF DIFFERENT OPTIONS
OF HIGH VOLTAGE LINE ROUTE

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CONSTRUCTION DE CRITERES "HABITAT"
POUR LA COMPARAISON DE DIFFERENTS TRACES
DE LIGNES A TRES HAUTE TENSION

RESUME

Ce cahier présente une méthode de comparaison de la sensibilité des habitants à différents tracés de lignes à Très Haute Tension. Cette méthode a été testée sur des cas pratiques.

Premièrement, nous créons des dimensions et des échelles spéciales de façon à évaluer les différentes zones de l'aire d'étude. Puis différentes options de tracés de lignes T.H.T. (qui sont une succession de zones) doivent être comparées.

La construction de critères permettant la comparaison de différentes options soulève un problème théorique : comment ponctualiser la distribution géographique des notes des différentes zones d'un parti ?

Plusieurs méthodes de ponctualisation sont proposées qui pourraient s'appliquer à d'autres domaines. Mais l'objectif de ce cahier est surtout de montrer que ces méthodes de ponctualisation ne sont pas neutres ; elles ne peuvent pas refléter, en un chiffre unique, toutes les caractéristiques d'une distribution de notes.

Mots-clés : Transport, Electricité, Localisation, Energie, Géographie.

CONSTRUCTING CRITERIA "POPULATION" FOR THE COMPARISON
OF DIFFERENT OPTIONS OF HIGH VOLTAGE LINE ROUTE

ABSTRACT

This paper presents a method for comparing the sensitivity of population between different possible options for the route of High Voltage transmission lines. It has been tested on practical cases.

First, we create special dimensions and scales in order to evaluate the different zones of a studied area. Then, the different options for the route of H V lines (which are a succession of different zones) have to be compared.

The construction of criteria permitting the comparison of different options raises a theoretical issue : how to punctualise the geographic distribution or the grades of the different zones of an option, in order to reflect preferences ? Different methods of punctualisation are proposed which could apply to other cases. But the purpose of the paper is overall to show that these methods of punctualisation are not neutral ; they cannot reflect all the characteristics of a distribution of grades.

Keywords : Transportation, Electricity, Location, Energy, Geography.

1 - INTRODUCTION

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This method is a part of a large study made for Electricité de France which aims at considering and taking into account living people in the choice of a HV line route. First, we made a qualitative study interviewing people concerned with HV lines, and we got an idea of the consequences of HV lines for inhabitants. We also noticed the importance of the decision process in people's feeling in front of a project of HV line in (11).

Then, we tried to construct criteria (to be used at the beginning of the decision process) of comparison between large options of HV line route. These criteria will help EDF and the impact study office to improve their proper conviction concerning the choice of an option, before external advices are required.

1 - 1. Objective :

Construction of criteria permitting the comparison of the sensitivity of population between different possible options for the route of high voltage transmission lines.

These criteria are constructed with the help of inhabitants' interviews and studies in the field. But, this is not sufficient and has to be completed by the feeling and experience of EDF. Finally, the criteria are defined with EDF, so that they represent the usually recognized impacts of H.V. lines on inhabitants. Consequently, these criteria will help EDF to reduce conflicts with inhabitants.

1 - 2. Hypothesis :

- We are interested in the comparison of large options and not of detail routes.
- We consider that an option is the successive crossing of several homogeneous zones.
- The evaluation of an option "A" is inferred from the valuations of the zones of this option "A". It requires the knowledge and use of one of the technically possible detail routes "R" inside this option "A". If the option "A" is then chosen, this detail route "R" will be compared with other detail routes inside this option "A", so that the best detail route is finally selected.

1. - 3. Definitions :

These definitions are adapted from B.ROY, 1985, Chap. 8,9 (8).

- Consequence : the effect or attribute or specific feature of a zone which is susceptible to interfere with the decision in question. (Here the decision is the choice of an option according to its impact on the inhabitants. A consequence may be the insecurity felt by inhabitants close to transmission lines).

- Dimension : consequences are connected with dimensions revealing preferences shared by the different actors.

Example : the insecurity is connected with the distance between the habitation and the HV line (high voltage line). This distance seems to increase when the density of population per km² decreases . Consequently, the density of population is a dimension.

- Category of dimensions : a category contains several dimensions of the same nature. Here, three categories of dimensions are defined :

- . the density of population,
- . the communal characteristics,
- . the landscape and living environment.

- Scale : a scale is connected with a dimension. A scale is a completely ordered set of states representative of all the possible states taken by a zone on this dimension. Here, we usually take numerical scales to reflect qualitative preferences.

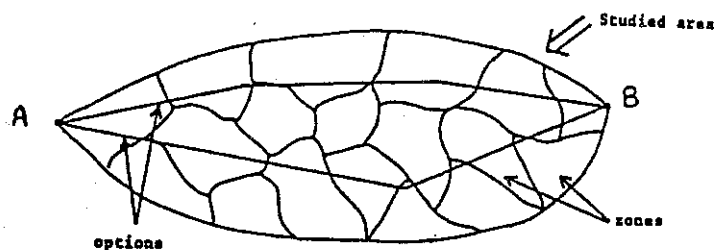
- Dispersion threshold : a dispersion threshold is associated with each scale so that the uncertainty and vagueness of data are taken into account.

- Zone : it is the largest part of the studied area which has an homogeneous valuation on each dimension.

- Option : it is the successive crossing of several zones which may connect the two ends of the HV line.

- Modulation : the modulation indicator gives complementary information about the way an option crosses the zones. It allows the ponctualisation of the different grades of the zones of an option, so that we obtain finally a set of valuations of an option on each category of dimensions. For instance, a km modulation indicator measures for a zone the length of the zone that is crossed by an option. Then , a km weighted average may be calculated for an option.

- Criterion : a criterion serves as a basis for judgment. Here, a criterion is a basis for the comparison between the impact on population of several options.



The studied area

1 - 4. The steps :

- First step : forming categories of dimensions with the different consequences of a HV line for the population.

- Second step : dividing the studied area in several zones of homogeneous sensitivity on each dimension. Valuating the sensitivity of each zone.

Zones	Category of Dimensions	Density of population	Communal characteristics	Landscape and living environment
z.1				
z.2				
z.3				
z.n				

Evaluations of the zones

- Third step : defining criteria of comparison between the options and evaluating the different options on these criteria. The issue of punctualisation is raised there.

criteria Options	Density		Communal characteristics	Landscape and living environment
	extreme	average		
A				
B				
C				
D				

Comparison of the options

2 - DEFINITION OF CATEGORIES OF DIMENSIONS REVEALING THE CONSEQUENCES

OF HV LINES FOR THE POPULATION

It seems that the consequences of HV lines on population (quoted in the studies in the field) could be divided in three categories of dimensions. We first list these consequences before we deduce the three categories which will be used after .

2 - 1. The consequences :

Let us study these consequences further.

- The noise : the perceived trouble seems to be an individual consequence often connected with the distance from the line to the habitation,

with the wind exposure, with the technical characteristics of the HV line.

Among these factors of trouble, only the distance from the line to the habitation can be taken into account, during the analysis of the studied area, in the sight of comparing large options.

- The prejudice to the environment : it includes the visual trouble, the degradation of the surroundings, the effect of saturation connected with the number of existing major facilities, the clearing of trees, the damage to the natural landscape, the aesthetic prejudice. The intensity of these impacts is a structural consequence depending on the kind of landscape but also a collective consequence depending on the communal characteristics (number of existing major facilities) and also an individual consequence (close visual trouble) depending on the distance from habitation to the HV line.

- The insecurity : (fear of falling down of the transmission conductors and of the structures...) This is an individual consequence depending on the distance from the habitation to the HV line, but also on the distance from the collective spaces to the HV line.

- The disturbance of property rights : Here we study the landed properties which are not used for a profession (agriculture, cultivation of woods...) ; that is to say : houses and gardens. The disturbance of property right usually depends on the distance from the line to the habitation

- Other consequences : The favourable or unfavourable impact of the HV line on the realisation of the communal projects, the disturbance or the intensification of the communal vocation are collective consequences depending on the communal characteristics.

The physical phenomena induced by the presence of a HV line (such as induced electric current...) are felt by people in or near to their house. They are individual consequences depending on the distance from the habitation to the line.

2 - 2. Categories of dimensions :

Three categories of dimensions are deduced from all these consequences :

- the category of dimensions : "density of population" which measures the likelihood that an habitation is close to the HV line. It measures consequently the intensity of individual consequences depending on the distance from the habitation to the HV line (noise, insecurity, disturbance of property rights...).
- the category of dimensions : "communal characteristics". This is a collective dimension which underlines the foreseeable perception of the line by the collectivity and its representatives (here : the town council).
- the category of dimensions : "landscape and living environment". This is a structural dimension which includes the morphological characteristics of the zone and the receptivity of the zone to a HV line on a landscape point of view. Surrounding degradation, damage to the natural landscape, aesthetic prejudice are evaluated with this category of dimensions.

For each category of dimensions, different information sources are employed. It is difficult to find these data ; it is also difficult to interpret the qualitative information given by people. But since this information is relevant with the choice of an option of HV line route, we have to take it into account although it is not quite precise. Statistic INSEE, map observance, aerial photography and field reconnaissance will make a fine evaluation of the density of population easier.

The subdivisions of the Departmental Equipment Direction and the Country planning office of the Departmental Direction of Agriculture will give us information concerning communal characteristics.

The category of dimensions "landscape and living environment" is evaluated with the assistance of the office charged with the impact study, field travelling, and aerial photographs.

3 - DIVISION OF THE STUDIED AREA IN HOMOGENEOUS ZONES AND

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EVALUATION OF EACH ZONE

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3 - 1. A basic division : the communal division ; justification

The inhabitants' sensitivity to the HV line passage usually involves a communal sensitivity made explicit by its representatives. The Mayor expresses this sensitivity when his advice is required before the "public utility declaration". The Mayor brings to light the problems of the commune and of its inhabitants in this occasion. So the entity "commune" is representative of a collectivity and its inhabitants.

Moreover, data concerning the individuals and their habitat are studied on a communal level, in the INSEE census. This census gives us homogeneous data for each commune. These data are the most detailed statistics that can be found.

Consequently, the commune - smallest geographic unity that has got its proper representatives and has been treated in a national census - seems to be a good basic unity for the division of the studied area in homogeneous zones.

Nevertheless, the commune will not always be sufficiently homogeneous according to the deepness of analysis which is expected. So, in some cases, it is useful to divide a commune in several more homogeneous zones. This division work should be committed to the office charged with the impact study and it should integrate the initial state study.

It seems that when the studied area is very large, it is not always possible nor useful to multiply the number of zones at the beginning. One should prefer to improve the division when several large options (a few km wide) are selected.

3 - 2. Category of dimension : density of population :

3 - 2. 1. The definition of homogeneous zones inside a commune.

Each zone is evaluated by its density of population. According to the communal density of population and to the geographic distribution of

inhabitants, the communal division in zones may be improved or not.

Suppose D the density of population of a whole commune. Let us consider three classes of communes :

- communes having a high density
- communes having an intermediate density
- communes having a low density.

(1) communes having a high density ($D \geq 1000 \text{ inh./km}^2$)

The map of communal density of population in France (IGN) shows that these communes are few. They are usually urban agglomerations where the passage of a HV line must be avoided. If however, this passage cannot be avoided, only a detailed study would permit to find a possible corridor for the HV line. This is why, at the beginning, the whole commune is considered as an urban zone to be avoided. If a deeper study is then realized in order to know the commune better, a possible corridor for the HV line is considered at this time .

The number of habitations located at less than 500 m. from this possible passage of the HV line is evaluated (with the help of the black points representing houses - on the 1/25000 map or on aerial photographs - and of field reconnaissance).

Field reconnaissance and aerial photographs are nearly indispensable, because the rapid evolution of the urban or suburban zones often makes geographic maps unusable.

The number of habitations counted in this corridor is multiplied by the average number of inhabitants per habitation in the commune (given by the INSEE census) and divided by the estimated surface of this corridor.

We obtain then the density of population of this corridor. Remaining zones of the commune are evaluated according to this calculation and to the census data.

Summary : Suppose :

- . D density of population of the whole commune
- . S surface of the whole commune
- . P population of the whole commune
- . z_1 a 1 km wide corridor surrounding the passage found

in the detailed study. (We consider that beyond 500 m. around the HV line, or around a 1 km. wide corridor, the line has no direct influence on inhabitants).

- z_2, z_3 , the remaining zones of the commune
- sz_1 , surface of z_1
- mz_1 the number of habitations counted in z_1
- h the average number of inhabitants per habitation in the commune (given by the INSEE census)
- dz_1 the density of population of z_1
- dz_2, dz_3 the density of population of the remaining zones of the commune.

$$dz_1 = \frac{mz_1 \times h}{sz_1}$$

If z_2 and z_3 have the same density of population,

$$dz_2 = dz_3 = \frac{P - (mz_1 \times h)}{S - sz_1}$$

z_2 and z_3 are usually urban zones.

(2) communes having an intermediate density of population D such as $20 \text{ inh/km}^2 \leq D < 1000 \text{ inh/km}^2$. In these communes, a wide disparity of the distribution of population may exist and involves a greater or smaller likelihood of proximity between the HV line and the habitations.

In a first step we take off the agglomerations (isolated by the INSEE census) which are part of urban zones.

In a second step, we study the disparity of density of population in the remaining areas of the commune. If this disparity seems to be low, the remaining areas of the commune are regarded as one homogeneous zone. If this disparity seems to be important, we should separate the remaining areas of the commune in several zones of homogeneous density.

The density of population of each zone is calculated with :
the number of counted habitations, the average number of inhabitants per habitation and the estimated surface of the zone (as it was done for the density of the corridor in an urban commune).

Summary : Suppose :

- z_1 the agglomeration containing the town hall
- z_2, z_3 agglomerations of more than 250 inhabitants recorded by INSEE (an agglomeration contains more than 50 inhabitants distributed in habitations that are not distant of more than 200 m from another one).
- z_4, z_5, z_6 zones of sparse population
- mz_i number of habitations in z_i
- h the average number of inhabitants per habitation
- pz_i the population of $z_i = mz_i \times h$
- sz_i the surface of z_i
- dz_i the density of population of z_i

Then z_1, z_2, z_3 , are classed in urban zones. If their proper surfaces can be neglected in front of the communal surface, they are not considered if not, their surfaces and densities are estimated.

$$\text{For } z_i = z_1, z_2, z_3 \quad dz_i = \frac{mz_i \times h}{sz_i} = \frac{pz_i}{sz_i}$$

We have to verify that $\sum pz_i \approx P$
and $\sum sz_i \approx S$

(3) communes having a low density D below 20 inh/km²

These communes are numerous in France. The study of the map of communal density of population lets us suppose that, whatever the distribution of population in these communes is, the close proximities of habitations can be avoided. Consequently in such communes, we just take the INSEE census data without counting habitations on the map.

Suppose there are (besides the agglomeration containing the town hall) $r - 2$ agglomerations of more than 250 inhabitants. The $r - 1$ agglomerations are classed in urban zones. Their density of population is given

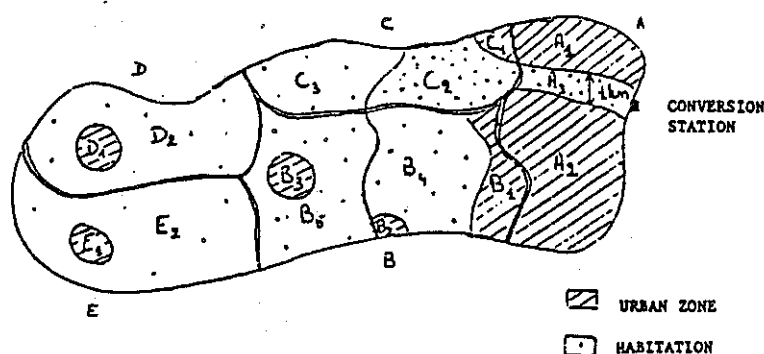
by the census and the estimation of their surface.

The density of population of the remaining area of the commune is :

$$dz_r = \frac{P - \sum_{i=1}^{r-1} pz_i}{S - \sum_{i=1}^{r-1} sz_i}$$

(if we use the same notations as above).

(4) example :



Example of the division of a commune according to the density of population

Suppose :

- . DX density of population of the whole commune X
- . DX_i density of population of the zone X_i
- . A, B, C, D, E , are 5 communes
- Commune A : $DA > 1000 \text{ inh/km}^2 \Rightarrow$ we have to look for a corridor.
- A_1 and A_2 are urban zones whose density d is over 1000 inh/km^2
- $da_3 = \frac{\text{number of habitations of } A_3 \times \text{average number of inh/hab.}}{\text{Estimated surface of } A_3}$

- Commune D : $20 < DD < 1000 \text{ inh/km}^2$

$$dD_1 > 1000$$

$$dD_2 = \frac{\text{Communal population} - \text{agglomerated population}}{\text{surface of D}}$$

- Commune B : $20 < DB < 1000 \text{ inh/km}^2$

$$dB_1 > 1000 \quad)$$

$$dB_2 > 1000 \quad) \quad \begin{array}{l} \text{the population of } B_1, B_2, B_3, \text{ are known from} \\ \text{the census (agglomerations of more than 250 inh.)} \end{array}$$

$$dB_3 > 1000 \quad)$$

The separation between B_4 and B_5 depends upon the landscape but these two zones have homogeneous density of population.

$$dB_4 = dB_5 = \frac{\text{Communal population} - \text{agglomerated population}}{\text{surface of } B_4 + \text{surface of } B_5}$$

- Commune C : $20 < DC < 1000 \text{ inh/km}^2$

$$dC_1 > 1000$$

The sparse population is not distributed in an homogeneous way.

We have to count the number of habitations of C_3 and to estimate the surface of C_3 .

$$dC_3 = \frac{\text{number of habitations of } C_3 \times \text{average of inh/habitation}}{\text{surface de } C_3}$$

$$dC_2 = \frac{\text{Communal population} - \text{population of } C_1 - \text{population of } C_3}{\text{surface of } C_2}$$

- Commune E : $DE < 20 \text{ inh/km}^2$

We do not include the disparities of population in sparsely populated zones.

$$dE_1 = \frac{\text{agglomerated population}}{\text{surface of } E_1}$$

$$dE_2 = \frac{\text{sparse population}}{\text{surface of E} - \text{surface of } E_1}$$

3 - 2. 2, Evaluation of each zone.

After this division of the commune in several zones, a figure can be associated with each zone of the studied area which measures the density of population of the zone.

Dispersion threshold : this threshold allows us to take into account uncertainty, vagueness and indetermination of the measures.

In fact, the evaluation induces errors or vagueness, particularly when the population of a zone is estimated by counting the habitations on a map.

Moreover, we should use densities, regarding the future evolution of population .

Taking into account these uncertainty and imprecision, it seems realistic to keep a threshold of $\pm 20\%$. In other words : for a result of 30 inh/km² the threshold is ± 6 inh/km² ; for a result of 60 inh/km² the threshold is ± 12 inh/km².

In France we have an average 2,7 inhabitants per habitation. This allows a margin of ± 2 habitations for a density of population of 30 inh/km².

If a zone is crossed by a HV line, its sensitivity to the line is all the more important as it is crossed on a wide length (the wider the "crossed" length, the more numerous the people touched by the line). Consequently, if an option crosses a zone, it is usefull to know the length on which it is crossed by this option.

3 - 3. Category of dimensions : communal characteristics

3 - 3. 1, Definition of the four dimensions.

The communal division is usually sufficient to isolate the sensitivity of a collectivity.

The communal characteristics and their compatibility with a HV line are to be evaluated. With the four following dimensions we try to describe the communal characteristics :

- the "communal vocation" measures the compatibility between the communal vocation and a HV line.
- the "communal projects" measures the compatibility between the realisation of communal projects and a HV line.
- the "demography" measures the compatibility between the demographic evolution and a HV line. Considering : the land allocation scheme,

the communal building projects, the past demographic evolution, we propose to use a simple scale

- the "local elements" measures the impact of other elements (different from the previous three dimensions) on the sensitivity of the commune in front of the HV line. This dimension integrates local elements (proper to the commune or to the region) and all the exceptional facts that are not integrated in the other dimensions. These elements may be of all sorts. We shall only evaluate their influence on the way the commune accepts a HV line.

Examples :

- presence of local associations
- assimilation between the HV line and other projects (electric power conversion station, electric power station).
- particular sensitiveness to another problem (pollution...) more important than a future HV line for the commune.
- other problems with local E.D.F.
- presence of reserved corridors in the land allocation scheme (POS)
- unbearable density of existing lines.

These dimensions are evaluated with the help of data provided by the subdivisions of the Departmental Equipment Direction and by the country planning office of the Agriculture Departmental Direction.

A special paper may be filled in for each commune, in order to precise the nature of the provided qualitative data.

These scales allow us to measure a qualitative phenomenon. In this way, we have an idea of this phenomenon, but it cannot be an exact measure of a reality which is in fact quite hazy.

For each dimension, a scale has been chosen ; it goes from 0 to 4.

The order of preference is increasing. The grade 0 has been chosen to characterize a state that supposes a high communal resistance to the passage of a HV line, whatever the other characteristics of the commune are. The grade 4 represents a state propitious to the line acceptance. The grade 2 reflects the neutrality or indetermination ; it always can be used in this sense.

When a grade is not needed for a dimension, it is not quoted.

If there is an hesitation between two consecutive grades, a medium grade may be introduced. Considering this possibility, we shall estimate that uncertainty is contained in a threshold of $\pm 1/2$ grade. The dispersion threshold for each scale is in this case $\pm 0,5$.

Grade Dimension	0	1	2	3	4
Communal Vocation	the touristie vocation of the zone is preponderant. For instance : tourism is an income source for the inhabitants; there are numerous secondary residences, campings, visited places or peculiar attractions (sea, mountains...)	the zone has not got the Grade 0, its urban or suburban vocation is preponderant. For instance : there are building plots or recent habitat (proving that this place has been chosen by the present inhabitants and not by their ancestors), or many inhabitants do not work in the commune, or there are many shops, or habitation tax is an income source for the commune.	the vocation of the zone is not clear, or the zone has no preponderant vocation. It has not got Grade 0 or 1. For instance : urban and agricultural zones or urban and industrial zones or touristie and rural zones.	the rural vocation of the zone is preponderant, it has not Grade 0, 1, 2. For instance : agricultural culture is a preponderant activity, family agricultural population = 1/2 communal population, the buildings are dispersed and old and they have an agricultural utility, or land taxes are communal income sources.	the preponderant vocation of the commune is industrial, the zone cannot get Grade 0, 1, 2, 3. For instance : there are many factories or big equipments, or professional tax is a communal income source, or low proportion of habitations compared with the proportions of industrial buildings or offices.
Communal Projects	there are one or several important projects which are not compatible with a new HV line whatever its route is. For instance : airport or VLM base or deltaplanes...	no communal project is incompatible with the crossing of the HV line, but some of them could be compromised by the HV line and may require some arrangements of the route or of the structures of the HV line. For instance : building plot project, leisure area, natural reserve...	the whole projects are compatible with a HV line (Grades 0, 1, 3, 4 are not relevant) or indetermination.	the whole communal projects are compatible with a HV line and some of them may be favoured by a HV line project. For instance : the financial income brought by the HV line is expected (tax on the structures), or improvement of power distribution in the commune could be realized with the help of special programs for electrification associated with the construction of a HV line.	the whole projects are compatible with a new HV line and an important communal project requires the construction of a new HV line. For instance : project of a factory supplied with the power of a new HV line.
Demography		Population is likely to increase in the next five years.	Population is likely to stagnate in the next five years.	Population is likely to decrease in the next five years.	
Local Elements	local elements let us suppose that a HV line would certainly not be accepted by this commune.	local elements let us suppose that a HV line would probably be refused by the commune.	local elements let suppose a real indifference or a feeling of powerlessness or an indetermination with respect to the possible reactions of the commune.	local elements let us suppose that a HV line is likely to be accepted by the commune.	local elements let us suppose that a HV line would certainly be accepted by the commune.

Description of the scales "communal characteristics"

3 - 3. 2. Synthesis of the four dimensions.

Every commune is valued on these four dimensions. But, since these four dimensions reflect the proper sensitiveness of a commune, it could be interesting to gather them in order to get only one grade for the communal sensitivity to a HV line according to the communal characteristics.

This grade should integrate the blinding effect of the grade 0 on a dimension. In other words, a very bad grade in a dimension cannot be compensated with good grades on other dimensions. If one of the communal characteristics is not compatible with a HV line, the commune is globally very affected by the crossing of a HV line, whatever its other communal characteristics are.

If we take the product of the grades on the four dimensions, we reflect the blinding effect of the zero on a dimension.

For each zone we obtain a sole valuation of the sensitivity of the communal characteristics going from 0 to $256 = 4^4$ (1)

Nevertheless if a zone is crossed by an option, the way the option crosses this zone (boundary crossing, or disruption in the urban web...) induces a different sensitivity that should also be taken into account.

3 - 4. Category of dimensions : "landscape and living environment".

3 - 4. 1. The division of the studied area in homogeneous zones determines wide landscape zones in the studied area.

Since these limits are often hazy, we shall try to identify them with the boundaries of the commune or with the boundaries of the population zones, so that we don't create too many zones.

3 - 4. 2. Evaluation of a zone. (this evaluation is inspired by the document : "Electric HV lines and Landscape"(3)).

The sensitivity of each zone is then evaluated. Two dimensions interfere with the measure of this sensitivity, they are :

morphological characteristics

landscape atmosphere.

(1) In fact the grade 4 is never taken on the dimension "demography", so, the product goes from 0 to 192 ($4^3 \times 3$).

Morphological characteristics

The scale varies from 0 to 50. It integrates :

- the vision scale : distance from which the landscape is no more perceived
- the internal scale : size of the components of the landscape.
- comprehension : organisation of the elements which constitute the landscape
- complexity : number of elements composing the landscape.

Description of the scale (increasing order of preference) :

grade 50 low sensitivity	large vision scale large internal scale high comprehension low complexity	} integration
	or	
	small vision scale small internal scale low comprehension high complexity	} absorption
grade 25	large vision scale medium internal scale high comprehension high complexity	}
	or	
	medium vision scale small internal scale medium comprehension high complexity	
grade 0 high sensitivity	{ in any other case	

When there is an hesitation between two consecutive grades, an intermediate grade may be introduced (12,5 or 37,5)

Landscape atmosphere

Several subdimensions constitute this atmosphere.

A zone is evaluated on these subdimensions.

Grade	0	5	10
Degree of rareness	rare	mixt	current
Degree of artifice	natural	"	artificial
Degree of mutation	immutable	"	unstable
Degree of novation	ancient	"	new
Degree of diversity	contrasted	"	monotonous

Description of the subdimensions "landscape atmosphere"

The sum of these 5 evaluations "Landscape atmosphere" goes from 0 to 50 (increasing preference order).

If there is an hesitation between two consecutive grades, it is possible to create an intermediate grade (2,5 or 7,5).

For these two dimensions uncertainty and imprecision induce a threshold of $\pm$ half a grade around a grade. The dispersion threshold is $\pm 12,5$ for each dimension.

In order to get only one grade per zone for the "landscape and living environment" (since landscape is also included in a chapter "leisure and tourism" of the impact study) we make the sum of the two dimensions (morphology and atmosphere) for a zone.

In fact, we suppose that those two dimensions have a similar importance when we measure the adaptability of a landscape to a HV line.

Each zone gets a grade "landscape and living environment" varying between 0 and 100. Moreover, when an option crosses a landscape zone it seems necessary to take care of the sensitivity of this zone but also of the length of the zone crossed by this option.

4 - EVALUATION OF AN OPTION, CHOICE OF CRITERIA OF COMPARISON BETWEEN

SEVERAL OPTIONS

4 - 1. Issues induced by the construction of criteria.

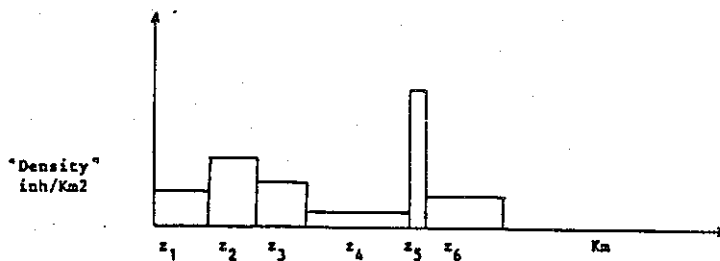
When each zone of the studied area is valuated on each category of dimensions and if we consider the other themes of the initial state of the impact study, it is possible to select several large options so that

they are compared.

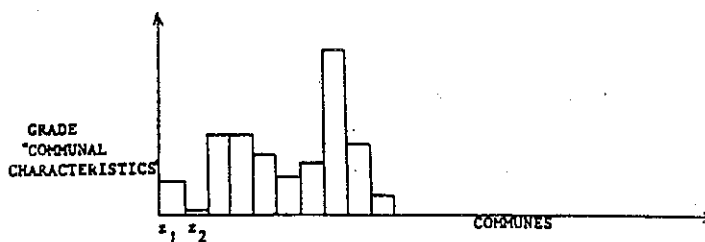
Each option can be represented by three histograms (one per category of dimensions).

We also have to take into account the margin of uncertainty around the evaluation of an option.

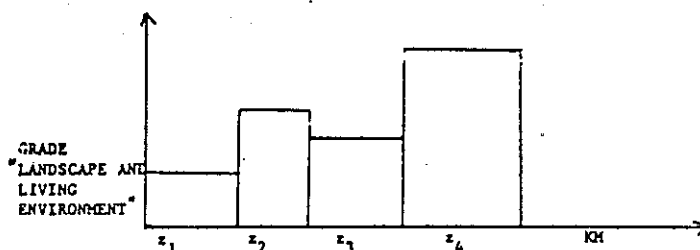
These margins of indetermination will be studied later on, and they will integrate the dispersion thresholds proposed above. At this stage of our work, the results given by the method should be considered cautiously because the significance of the difference between two evaluations on a criterion is not well-defined.



Histogram of density of population weighted by crossed Km.



Histogram "communal characteristics" doesn't include the way an option crosses a commune.



Histogram "landscape and living environment" weighted by crossed Km.

Each one of these three histograms represents a distribution of grades associated with an option.

Looking for a comparison between several options raises an issue, since each option is itself composed with a multitude of diverse valuations which vary according to the considered category of dimensions and according to the considered zone.

However, it seems impossible to keep integrally all these valuations and to compare them with the valuations of another option. Consequently, we try to keep only a few significant criteria representing an option. These criteria should reflect the preferences that E.D.F. wants to make conspicuous.

There are different technical ways of punctualisation. For each category of dimensions we tried to answer the following questions (°):

- Which modulation indicator shall we retain in order to precise the way a zone is crossed by an option (crossed length...).
- Which characteristic(s) of the distribution of grades on a category of dimensions for an option do we want to make conspicuous (extreme values, average value...) ? How many criteria are needed for that ?
- For each criterion, according to the point of view we want to reflect, can the grades of the distribution be compensated ? If yes, which method of compensation and agregation shall we use so that the evaluation of an option on this criterion makes sense ? (The calculation of an average or global value per option is realised cautiously. Shall we transform the existing ordinal scale for a category of dimensions so that compensations between grades reflect preferences ?) If no, can we define percentiles or fixed values in order to punctualise the distribution of grades?
- For each criterion, do we prefer to keep a "standardized" value independant of the sum of the modulation indicators of an option (such as an average, a median, a percentile...) or is it better to build a criterion depending on the sum of the modulation indicators (such as a weighted sum or the number of km2 overpassing a fixed value...)

We'll try to show how we answered these questions in the frame of this study.

(°) cf. ROY. chap. 9 (8)

In order to construct criteria and to isolate the preferences depending on a category of dimensions, we have to place us in the conditions that favour this isolation. In other words, we shall reason, other things being equal, as if the options compared in the experimentation were only differing, on the point we want to study, on a criterion.

Once the different criteria are constructed, it is possible to consider the reality ; complex options having different evaluations on many criteria

4 - 2. Criteria "density of population"

The passage from several figures to one or two figures is not neutral it insists on such or such characteristic and reflect some preferences.

4 - 2. 1. Criterion "extreme densities"

When we have the histogram "density of population" of an option (cf. p.20) a formal preference seems to be shared by everyone : the highly populated zones should be compared. This formal priority can be reflected in different ways :

- The "nth percentile" : the criterion "extreme densities" is measured by the density over which are the most populated $n/100$ km of an option.
 - The "maximum value" : the measure of the criterion "extreme densities" is here the highest density taken by a zone in an option.
 - The "very dense length" : the criterion "extreme densities" is the number of km of an option overpassing a limit of density fixed for the studied area according to the regional characteristics. This method has been chosen because it presents three advantages : it is adaptable to local characteristics, it is easily calculated, it takes into account all the difficult points (and not only one hard point as supposes the maximum value)
- So, the criterion "extreme densities" X for an option A of n zones could be written :

$$X(A) = \sum l_i / d_i \geq S$$

l_i = length crossed by option A in zone i

d_i = density of population of zone i

S = fixed value of density representing extremely dense zones.

4 - 2. 2. Criterion "intermediate density"

To examine the difficult points is not sufficient to compare the density of the options. Two options may have the same extreme densities and different average density : that implies a different difficulty of inserting the HV line among habitations.

Consequently, a measure of the intermediate density of an option should be defined.

We tested several methods of punctualisation in order to approach the ill-defined preferences of EDF . But the modulation indicator remains the same, it is the number of km crossed by an option .

- Average gross density weighted by crossed km : the preference order is decreasing. This method supposes that we are indifferent on this criterion between :

2 km of density 55 inh/km ²	average 55 inh/km ²
and	
+ { 1 km of density 10 inh/km ² 1 km of density 100 inh/km ² }	average 55 inh/km ²

other things being equal. But EDF seems to prefer the second option.

- Average of inverse densities weighted by crossed length.

We may consider that the difficulty of crossing a zone can be measured by the average available surface per inhabitant. In this case, we shall calculate the average of the inverse densities and not of the gross densities. The resulting average varies according to an increasing preference order (2 is preferred to 1) since we inverse densities.

That means there is indifference between :

2 km of density 18 inh/km ²	average 0,056 km ² /inh.
and	
+ { 1 km of density 10 inh/km ² 1 km of density 100 inh/km ² }	average 0,055 km ² /inh.

other things being equal. But EDF seems to prefer the first option .

- Average of the probable distance between habitations weighted by the cross length. Here, we estimate that the difficulty of passing a HV line in a zone is connected with the possible distance between two habitations. A density of D inh/km² supposes a density of $\frac{D}{2,7}$ habitations/km² (since there are 2,7 inhabitants per habitation in France on average).

The average distance between two habitations is then :

$$\sqrt{\frac{1}{\frac{D}{2,7}}} = \sqrt{\frac{2,7}{D}} \quad \text{km}$$

This transformation of the scale of densities induces a new scale, its order of preference is increasing (0 is worse than 1).

there is indifference with this method between :

$$\begin{array}{lcl} \text{and} & \left. \begin{array}{l} 2 \text{ km of density } 23 \text{ inh/km}^2 \\ 1 \text{ km of density } 10 \text{ inh/km}^2 \\ + 1 \text{ km of density } 100 \text{ inh/km}^2 \end{array} \right\} & \begin{array}{l} \text{average } 0,34 \text{ km} \\ \text{average } 0,34 \text{ km} \end{array} \end{array}$$

other things being equal. But EDF seems to prefer the first option .

- Average of the logarithms of the density weighted by the crossed length.

The use of a logarithmic scale for the representation of the densities favours the differentiation between low densities but reduces the importance of high densities. The order of preference is decreasing.

With this method there is indifference between :

$$\begin{array}{lcl} \text{and} & \left. \begin{array}{l} 2 \text{ km of density } 32 \text{ inh/km}^2 \\ 1 \text{ km of density } 10 \text{ inh/km}^2 \\ + 1 \text{ km of density } 100 \text{ inh/km}^2 \end{array} \right\} & \begin{array}{l} \text{average } 1,5 \\ \text{average } 1,5 \end{array} \end{array}$$

other things being equal. But EDF seems to prefer the first option .

- The median value (modulated by the crossed length).

It is the density associated with the zone that shares in two equal lengths, the zones of the option ranked by increasing density order.

The order of preference is decreasing.

With this method there is indifference between :

$$\begin{array}{lcl} \text{and} & \left. \begin{array}{l} 2 \text{ km of density } 10 \text{ inh/km}^2 \\ 1 \text{ km of density } 10 \text{ inh/km}^2 \\ 1 \text{ km of density } 100 \text{ inh/km}^2 \end{array} \right\} & \begin{array}{l} \text{median } 10 \text{ inh/km}^2 \\ \text{median } 10 \text{ inh/km}^2 \end{array} \end{array}$$

other things being equal . But EDF prefers the first option .

These examples show that before calculating an average density weighted by the crossed length, it is important to choose a function transforming the density of population which better reflects preferences and which makes the operation of average sensible . Since these functions are not in accordance with EDF preferences, we are now constructing a function with the assistance of preferences given by EDF people . These preferences will be inferred from

comparisons between fictitious options having the same length but a different distribution of densities . This function will be used to calculate a weighted sum, because it seems that the local length of the line is related with the measure of direct impact on population : for equal densities , a larger line causes more damage .

The criterion D "intermediate density" could be written for an option A of n zones :

$$D(A) = \sum_{i=1}^n l_i f(d_i)$$

d_i = density of the zone i

l_i = length crossed by option A in zone i.

4 - 2. 3. Criterion "communal characteristics"

For an option we dispose of an histogram "communal characteristics" (cf. p. 20). Each commune is valuated by a grade between 0 and 256. We have now to define the criterion permitting the comparison between the communal characteristics of different options. In other words, we shall replace this distribution along an option by a sole evaluation for an option. It is not possible to calculate the product of the grades of the different communes of an option. In fact, this method would suppose that when a commune has the grade 0, the whole option gets the grade 0.

It seems better to calculate an average or a sum of the grades of the communes. This average or sum supposes that the comparison of the differences between two grades makes sense, since an average or sum implies compensations between the grades.

Consequently, if we compare several options calculating the average of the product of their communal characteristics, other things being equal; knowing that a commune valuated (2;2;2;2) has the grade 16 , a commune valuated (4;4;4;4) has the grade 256 ,and a commune valuated (1;1;1;1) has the grade 1 ; the option 1:one commune (2;2;2;2) plus one commune (4;4;4;4) (average :136) is widely preferred to the option 2: two communes (3;3;3;3) (average :81) ; while E.D.F. is indifferent between option 1 and option 2 .

Similarly other things being equal, the option 3: one commune (0;0;0;0) plus one commune (4;4;4;4) (average :128) is preferred to the option 4: two communes (2;2;2;2) (average :16) ; while E.D.F. is indifferent between option 3 and option 4 .

Calculating this average of gross products implies that an option whose communes have medium grades is more penalized than an option whose zones

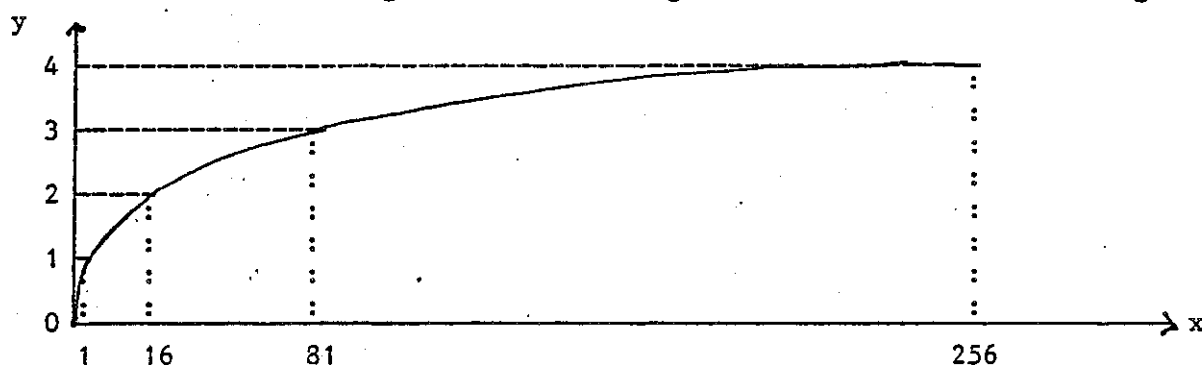
have very good and very bad grades .

Moreover, the discrepancies induced by the gross product makes the association between a medium zone and the grade located in the middle of the scale, impossible.

For instance : a medium zone valuated (2;2;2;2) gets a gross product of 16 which is very far from a zone valuated (4;4;4;4) gross product : 256, and very close to a zone valuated (0;0;0;0) gross product 0.

It seems better to transform this product so that : the product 16 is transformed into the grade 2 ; the product 256 is transformed into the grade 4 and the product 0 remains 0.

This transformation gives us more significant transformed histograms.



This curve $y = \sqrt[4]{x}$ permits to solve the same kind of problems as the problems which exist for the construction of the criteria density of population. In other words, we must answer the question : "How can we change the scale associated with a category of dimensions, so that the calculation of an average or sum makes sense ?"

With this curve, we can calculate an average or sum of the transformed products of communal characteristics which makes sense.

However, we observed that the importance of the communal characteristics varies with the place where the HV line crosses the commune. This is the reason why a "crossing" indicator has been defined ; it will rectify the importance of the communal characteristics according to the place where the HV line crosses the commune. It seems that the impact of a line on communal characteristics is also linked with the number of crossed commune and with the way they are crossed. So we'll calculate a weighted sum of the communal characteristics of an option and not an average which would not take into account the global communal impact.

The calculation of this weighted sum supposes that the communal characteristics and the number of communes vary in the same sense, with regards to the preference. It is not the case here, the highest $\sqrt[4]{x}$ is preferred while the lowest number

of crossed communes is preferred . Consequently, we consider the complement of $\sqrt{x}$ $4-\sqrt{x}$ which varies in the same direction as the number of crossed communes .

We shall distinguish four possibilities for the HV line to cross a commune :

- A : the commune is only crossed on its borders in a favourable way. No urban zones or zones having priority are crossed.
- B : the crossed zones are neither urban nor developing but the line doesn't only follow the borders.
- C : one of the crossed zones is reserved for communal activities or projects (building plot, leisure area, constructions...). None of the zones is urban.
- D : one of the zones crossed by the line is urban. And the presence of the HV line implies a disruption in the urban network.

The diminution of the communal grade has to reflect preferences of choice between several options.

In order to consider these preferences, we propose some equivalences that fix the valuation of the "crossing" indicator. The grade of a commune is $\sqrt{x}$, and we use its complement $4-\sqrt{x}$ in the weighted sum .

One commune of grade 3 and crossing indicator C is equivalent with one commune of grade 2 and crossing indicator B .

One commune of grade 0 and crossing indicator A is equivalent with one commune of grade 2 and crossing indicator B .

One commune of grade 0 and crossing indicator B is equivalent with one commune of grade 2 and crossing indicator C .

One commune of grade 0 and crossing indicator C is equivalent with one commune of grade 1 and crossing indicator D .

If the "crossing indicator" is D the grade is not reduced. So $D = 1$.

These equivalences imply equalities :

$$C(4-3) = B(4-2),$$

$$A(4-0) = B(4-2),$$

$$B(4-0) = C(4-2),$$

$$C(4-0) = D(4-1).$$

We infer : $C=0,75$; $B=0,4$; $A=0,2$.

This crossing indicator is used for the modulation of the transformed product for an option. The criterion "communal characteristics" C for an option A of n zones is then :

$$C(A) = \sum_{i=1}^n m_i f(c_i)$$

m_i = modulation indicator of the zone i

$f(c_i) = 4 - \sqrt[4]{c_i}$ = transformed product of the communal characteristics of the zone i.

4 - 2. 4. Criterion "landscape and living environment"

Each zone is evaluated from 0 to 100 on the category of dimensions "landscape and living environment".

When different options are chosen, each of them may be represented by an histogram "landscape and living environment" (cf.p.20) integrating the number of crossed km.

As for the density and communal characteristics, we try to construct a criterion "landscape and living environment" in order to compare options.

This criterion is constructed with the help of the distribution along an option of the grades "landscape and living environment". Transforming this distribution in a criterion supposes that we introduce a modulation indicator (the crossed length). Three methods may be used for the construction of a criterion "landscape and living environment".

1st method

We calculate the average of the grades "landscape and living environment" weighted by the crossed km (as for the average of gross densities).

This average is not really adapted to this category of dimensions since the valuations "landscape and living environment" would not be easily compensated.

2nd method : Calculation of the median

The median is the grade "landscape and living environment" that shares in two equal lengths the zones ranked from the worst to the best valuation. This median doesn't vary for an option, whatever the transformation of the scale "landscape and living environment" is. Moreover, the median doesn't imply compensation phenomena, it only permits to assert that 50 % of the total length of an option has a grade overpassing the median grade X.

But the median supposes that we do not take into account the global length (and so global impact on landscape and living environment) of an option : that's why we propose a third method.

3d method : the sensible length

We choose a grade over which the "landscape and living environment" sensitivity is important. That could be 50. The sensitive length is, for an option, the length of the crossed zones which grade is overpassing 50. This method doesn't imply any compensation between grades.

The criterion "landscape and living environment" E for an option A of n zones is then :

$$E(A) = \sum_{i=1}^n l_i \quad \text{with} \quad e_i < 50$$

l_i =length crossed by option A in zone i

e_i =grade "landscape and living environment" of zone i.

5 - CONCLUSION

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At this stage of the decision process we have just tried to propose some significant criteria for the comparison of the impact on population of different options of HV line routes. We can now get a table where each option is valuated on each criterion. This is the kind of decision aid we were asked for. A further research could lead to shape other criteria related to agriculture, technical difficulties... Implementing a process of selection or ranking of options would be more difficult because we are facing conflicting points of view.

But this work can already provide some aid : it supposes a systematic search for information in each zone; consequently, it may generate new options, it makes also the consequences of each option on population more clear and so gives a basis for discussing or preparing decision.

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