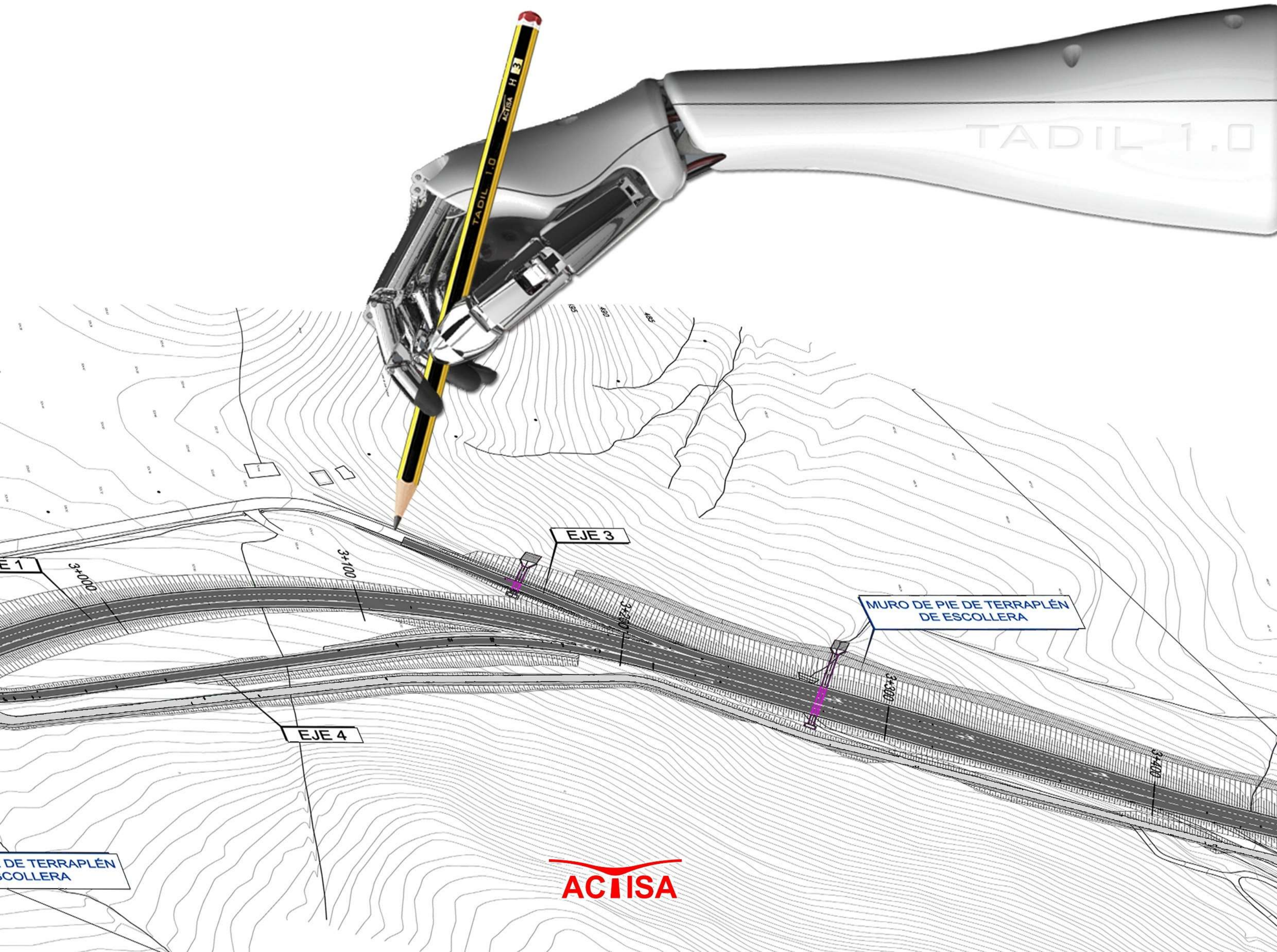
TADIL 3.0

TENCHIQUES FOR THE AUTOMATIC DESIGN OF NEW LINEAR INFRASTRUCTURES

METHODOLOGICAL APPLICATION GUIDE

TADIL-Road



ACTISA

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES (TADIL)

ACTISA

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES PROJECT

METHODOLOGICAL APPLICATION GUIDE

CONTACT INFORMATION:

ACTISA S.L. (Actividades de Consultoría Técnica, Investigación y Servicios Avanzados S.L.).

C/Manuel Roldán Prieto, 3, 2º F. 18140 La Zubia, (Granada).

Phone and fax: +34.958.38.92.74

www.actisa.net

E-mail: actisa@actisa.net

PRESENTATION

TADIL "Techniques for the Automatic Design of Linear Infrastructure" makes use of techniques in the field of artificial intelligent which open a new panorama in the field of civil engineering.

These computer based solutions make the engineer's work easier, providing a greater view of study and a higher efficiency in generating alternatives and studying the land. Likewise, entering a wide range of land parameters will provoke more integrated solutions and with less environmental impact.

This Guide provides all the application concepts for carrying out a complete study of infrastructures in the land. We seek this Guide to be accessible for the user, hence we explain quite simply the technical terms of application in TADIL.

The Guide is complemented with the User's Guide of Software TADIL, where we deal with the software use without going into application concepts and we carry out a complete example of Previous Study and Informative Study.

We wish this Guide to arouse the highest interest among the users, so that they feel that applying TADIL to their projects in civil construction is easy.

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ECONOMIC INTEREST GROUP TADIL PROJECT

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES

Methodological Application Guide

CHAPTER 1. GENERAL METHODOLOGY.

EDITION 1.

This chapter describes the contents of the TADIL software Methodological Guide.

It also attempts to serve as an initial point of reference for the user and to provide a step-by-step guide for creating Previous Studies and Informative Studies.

Finally, it tackles the first stage of the study: creating a digital model of the territory and generating the territorial information layers.

CHAPTER 1. GENERAL METHODOLOGY.

SUB-CHAPTER 0. AIMS AND STRUCTURE OF THE GUIDE.

0. Introduction

This section illustrates the purpose of this guide and includes a description of its chapters. It must therefore be read by the user before passing on to the next chapter.

1. Aims of the Methodological Application Guide

Unlike the TADIL software User's Manual, with which the user can learn how to install the software, use the different menus and input information, the Methodological Application Guide provides a global vision of the project. It describes the differences between a Previous Study and an Informative Study, it defines the steps that must be taken by the user and describes in detail the meaning of each of the variables inserted into the program. Also, this guide tries to be as universal as possible, so that the technical concepts used throughout the program are clear and easy to understand.

2. Structure of the Guide

The guide is structured into the following chapters:

- *CHAPTER 1. GENERAL METHODOLOGY*
- *CHAPTER 2. GEOGRAPHICAL INFORMATION SYSTEM (GIS)*

This chapter deals with the input of all the land variables that influence the drafting design or the evaluation of the alternatives carried out in the multicriteria analysis.

- *CHAPTER 3. CONSTRUCTION UNITS AND PRICES*

This chapter describes the construction units that allow obtaining the budget of each alternative.

- *CHAPTER 4. TYPE SECTIONS*

This chapter defines the type sections that are available for obtaining the cross sections, the measurements, the earthworks balance and the budget.

- *CHAPTER 5. BUDGET AND PROFITABILITY*

This chapter describes how the budget of each alternative is obtained, and the process followed by the program for obtaining the earthworks balance. Similarly, it also describes the variables that have an impact on the profitability of each alternative.

- *CHAPTER 6. MULTICRITERIA EVALUATION.*

This chapter describes the procedure for obtaining the multicriteria subjective score of the selected alternatives.

- ***Chapter 7. Creation of drafts***

This chapter describes the methodology for obtaining the different route alternatives, the selection of the regulations and the description of the variables that have an impact on the definition of the different solutions.

CHAPTER 1. GENERAL METHODOLOGY.

SUB-CHAPTER 1. TYPES OF STUDIES

1. Types of studies.

TADIL is the ideal software for developing Previous Studies and Informative Studies that allow the creation of route alternatives.

The difference between these two types of analysis lies in the amount of preliminary knowledge of the territory:

- In the Previous Study, there is not a detailed study of the variables that define the territory. The infrastructure that is going to be designed tries to solve a problem between a start and end point. It usually begins with a detailed study of the traffic or a traffic demand analysis, although the type of infrastructure that is going to be built is not specified yet.
- In the Informative Study, the characteristics of the route are given in advance. Also, there is a complete study of the variables in the territory that have an impact on the draft (environmental, geotechnical, climatic, socio-economic, patrimonial, etc.).

In the following table, we can see the difference between these studies:

	Previous Study	Informative Study
Drafting	The type section is determined by a study of the traffic. However, a range of speeds is considered, and so are a range of geometrical characteristics in the longitudinal and cross sections of the new infrastructure. The Previous Study specifies it with implantation tests of routes on the territory.	In this case, the type section and speed of the project have been defined, and the alternatives should comply with the order of study that determines these values. The creation of the route alternatives should allow the development of a detailed multicriteria study.
Cartography	Published maps with scales from 1:25,000 to 1:5,000 are used.	In this case, specific maps will generally have been produced, describing the area of study.
Costs	Only the global costs regarding the implantation, cut, fill, structures and tunnels are used.	It allows using the suitable construction units, according to the geotechnical groups that are crossed, the earthworks, pavements and esplanades, as well as the different types of tunnels and structures.
Geotechnics	The starting points are regional studies of the geology and geotechnics that include general suggestions for fill slopes and cut slopes.	Detailed studies that allow differentiating areas and geotechnical groups with specific information on the slopes, protections, scaling, pavement and esplanades are used.
Structures and tunnels	Only the global costs are taken into account.	It allows making a distinction between the types of structures and tunnels, and the costs divided into areas.

	Previous Study	Informative Study
Environment	This includes only environmentally protected areas through which the infrastructure cannot cross.	It allows implementing a wide array of variables determined in a comprehensive environmental study. It bans the infrastructure from crossing certain areas depending on the score of the different variables.
Climatology	It is usually not taken into account, except for the climate in general terms.	It allows implementing studies on aspects that influence the traffic, such as frost, rain, fog, wind, etc.
Socio-economics	Only the aspects regarding the forecast of traffic are considered.	A complete study of the land uses with their corresponding productive score is usually included.
Patrimony	Only the areas with patrimonial protection that cannot be crossed are implemented.	It allows a wide study of the evaluation of the terrain, crossing of infrastructures, farm tracks, etc.

Table 1-1. Comparison between Previous and Informative Study.

The Previous Study generally precedes the Informative Study, and provides information on the type of infrastructure that is to be developed in the territory.

TADIL allows creating Previous Studies without having to implement the GIS Menu, the Construction Units Menu or the Type Sections Menu. The information is inserted in the Draft Menu (TDI).

On the other hand, when the user is developing an Informative Study, the variables must have been previously inserted into the GIS Menu, together with the values of the construction units and the type sections that are to be implemented. Once the information is inserted, the user can access the Draft Menu and create the alternatives.

The information that can be obtained in each type of study greatly differs, as described below:

- ***PREVIOUS STUDY:***
    - *Route plan axis*
    - *Longitudinal profile*
- ***INFORMATIVE STUDY:***
    - *Route plan axis*
    - *Longitudinal profile*
    - *Cross sections*
    - *Earthworks plan*
    - *Budget and earthworks balance*
    - *Profitability results*
    - *Evaluation of the alternative*

CHAPTER 1. GENERAL METHODOLOGY.

SUB-CHAPTER 2. STAGES IN THE DEFINITION OF STUDIES.

1. Stages for the creation of a Previous Study

To create a Previous Study, the user will only have to access the Draft Menu. Beforehand, the cartography of the territory must have been mapped. The following information is to be considered:

- *Type of road and design speed.*
- *Maximum and minimum slopes.*
- *Areas which are banned.*
- *Maximum height of cut sections and fill sections, measured at the axis.*
- *Width of platform.*
- *Possibility of inserting structures and tunnels.*
- *Global costs concerning implantation (these can be excluded if this parameter is not considered in the dynamic assessment of the route).*
- *Design preferences.*

The result is the route plan axis and the longitudinal profile of the alternatives that are feasible.

2. Stages for the creation of an Informative Study

When the user creates an Informative Study before accessing the Draft Menu, the corresponding information must be completed in the Construction Units Menu, Geographical Information System Menu and Type Sections Menu.

- *The user must complete at least one general geotechnical area.*
- *Similarly, the user must input the construction units used in the general geotechnical area.*
- *Finally, a type section must be selected.*
- *If the option of routes with structures and tunnels is selected, at least one general area must be inserted for both cases, and the construction units used in these menus must be defined in the Construction Units Menu.*

Once all of this information is inserted, the Draft Menu can be accessed and the Informative Study can be selected.

Then the user can obtain the plan axis and the longitudinal profile. Once the type section is selected, the cross sections and the earthworks plan can be obtained.

Once achieved, the user can continue to obtain the following:

- Earthworks balance and budget
- Profitability
- Evaluation of the alternatives

In order to obtain a good score of the alternatives, it is recommended that the information inserted in the GIS Menu is wide-ranging regarding these variables: geotechnical, structures, tunnels, environment, climatology, socioeconomics and patrimony.

For this, the user must have previously filled in all of the information that is required in each menu.

The user can name each route with the same name with which it was saved, obtaining the earthworks balance, budget, profitability and score.

Therefore, the steps to obtain an Informative Study in the TADIL software are as follows:

1º. Creating maps, digital model of the territory and management of layers

2º. Inserting the database construction units to be used

3º. Inserting the data from the Geographical Information System

4º. Defining type sections

5º. Inserting the data in the Draft Menu and obtaining the route alternatives with their plan and profile axes

6º. Selecting the type section in the Draft Menu and obtaining the cross sections and the earthworks plan

7º. Inserting the information of the budget and obtaining the earthworks balance and the budget

8º. Inserting data on the profitability and obtaining the economic feasibility results

9º. Selecting the alternatives in the Evaluation Menu and producing the multicriteria analysis of all of them

10º. The user can select the alternative that is considered the most suitable

11º. Obtaining listings and plans

CHAPTER 1. GENERAL METHODOLOGY.

SUB-CHAPTER 3. CARTOGRAPHY AND MANAGEMENT OF LAYERS.

1. Cartography

The user will follow the procedure indicated in the User's Manual for creating the digital model of the territory.

It is worth mentioning that great part of the study depends on the quality of the cartography that has to be mapped. Therefore, it is very important that the user dedicates all the time necessary in creating the maps.

The existence of break lines that define the ruptures of the slope or the encounter of different planes is relevant in this cartography. The triangulation of the digital model depends on these lines.

Similarly, the elevated starting points and polylines should have an adequate separation, avoiding blank spaces or undefined areas.

2. Management of layers

It is highly recommendable that the user arranges the information that has to be inputted before implementing it in the TADIL software. The program creates independent layers for each territorial variable inserted in the GIS. When the user imports the information, it is recommended that he or she previously creates sector information folders, such as environment-fauna, environment-flora, etc.

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES (TADIL)

CHAPTER 2
GEOGRAPHICAL INFORMATION SYSTEM (GIS)

METHODOLOGICAL APPLICATION GUIDE

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TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES

Methodological Application Guide

CHAPTER 2. GEOGRAPHICAL INFORMATION SYSTEM

EDITION 1

This chapter provides a description of the variables included in the Geographical Information System (GIS) that define the territory and have an effect on the automatic calculation of route alternatives, as well as on their evaluation.

The variables are classified under two types: determining variables and qualitative variables. The determining variables have an impact on the daft search algorithms (they determine the calculation of the route). The qualitative variables are only taken into account in the evaluation of the alternatives once they are calculated. The qualitative variables can determine the route if the user bans the infrastructure from crossing areas with a given characteristic, such as a Nature Reserve or a specific protected fauna area.

In this chapter, the GIS variables and their implementation are described from an engineering viewpoint. The main goal of this chapter is to provide the user with a practical overview of the territory, constituting a useful and effective tool for the consultant, administrator or promoter of the project at hand.

GEOGRAPHICAL INFORMATION SYSTEM

SUB-CHAPTER 0. PROCEDURE

0. Introduction

This chapter describes the territorial variables that can be selected for determining the route alternatives, as well as for the final evaluation of these alternatives.

1. Methodology

The variables of the Geographical Information System can be classified into two groups:

- Determining variables of the GIS: They affect the definition of the alternatives in the different algorithms included in the automatic design of plans and longitudinal sections of infrastructures. Also, the entries of these variables incorporate a subjective score given by the user in order to allow a qualitative evaluation of the different alternatives.
- Qualitative variables of the GIS: They offer a qualitative and subjective evaluation of the different alternatives. These variables, in turn, condition the route when the "Ban Passage" option is enabled in an area with a given entry of the variable. For instance, in the variable "Fauna" and the entry "Vertebrates in danger of extinction: bearded vulture", the option "Ban Passage" can be activated. As a result, the design algorithms avoid passing through that area.

There is another special group of variables that can also be considered determining variables of the GIS:

- Route variables with GIS format: Unlike most drafting programs, in which the input of the information on the type section can only be done once the plan and profile are defined, in the TADIL software the information is added in GIS format, thus differentiating geographical areas. Consequently, the type section of a road or railway in a predominantly clayey area will not be the same as in a rocky area. The program automatically assigns a type section when it identifies the areas that belong to the axis point of the plan of each cross section.

2. Impact on the definition of routes

As described in Chapter 1, in order to calculate the route alternatives, the variables inserted in the GIS of the program can be enabled (Informative Study) or disabled (Previous Study).

These variables can be enabled to obtain a more comprehensive study of the infrastructure. The variables of the GIS can be disabled to generate a quick analysis of the capacity of reception of infrastructures within a given territory when there is not a detailed Previous Study of its characteristics.

In general, Informative Studies require a comprehensive study of the territory and of its variables. In contrast, there is much less information in Previous Studies.

3. Evaluation of alternatives

Determining and qualitative variables allow valuating the alternatives according to a subjective score specified by the user, in addition to their evaluation percentages. This evaluation allows selecting the best solution.

The evaluation of the GIS variables is performed together with other parameters derived from the quality of the route, such as length, average speed, variables of profitability, etc.

The subjective evaluation of the variables is scored from 0 to 10. A higher score indicates a larger impact, and therefore a worse outcome. A zero (0) indicates that there is a minimum impact or that a maximum optimization has been obtained. A ten (10) indicates the highest impact or the worst comparative result.

A thorough Informative Study requires a comprehensive analysis of the variables of the GIS and of the corresponding sensitivity analysis that will allow evaluating the different route options between the start and end points. The quality of the route and the reception capacity of the territory must be adequately taken into consideration.

GEOGRAPHICAL INFORMATION SYSTEM

SUB-CHAPTER 1. SELECTION OF VARIABLES

0. Introduction

This chapter describes the variables of the Geographical Information System that are taken into account in the design and the evaluation of the routes.

1. Groups of variables

In general, the variables that are evaluated are those that are most common in the drafting of Previous Studies, Informative Studies, Basic Projects, Preliminary Proposals, Public Biddings and Environmental Evaluation Studies of Infrastructures.

A common group of variables of the GIS is the following:

- Geotechnical variables
- Geomorphologic variables
- Environmental variables
- Climatic variables
- Socio-economic variables
- Patrimonial variables

In turn, as mentioned above, the route variables are assigned as GIS variables in the following manner:

- Variables of a conventional section in cut sections or fill sections: these are defined as geotechnical variables.
- Defining variables of tunnel-type sections: these are defined as geotechnical variables.
- Defining variables for the foundation of structures: these are defined as geotechnical variables.
- Variables that define the type of structures: these are defined as an independent group. The reason lies in the fact that the type selected by the user may differ clearly from the geotechnical characteristics of the environment, and moreover:
  - There may be areas where the aesthetic of the structures is a top priority (places that are more visible from urban surroundings or viewpoints).
  - Geographical fields can be selected where special structures are required (for example, cable-stayed bridges with wide-spanning arches).

2. List of variables

Next is a list of the variables that are included in each of the abovementioned groups.

- <u>Geomorphologic variables:</u>
  - Height over sea level (metres above sea level).
  - Clinometry: maximum slope of the terrain (%).

- <u>Geotechnical variables:</u>

  - Geotechnics of Earthwork:
    - *Geotechnical risks.*
    - *California Bearing Ratio (CBR) / Classification of the Underlying Natural Soil (UNS).*
    - *Excavated materials used in the construction work.*
    - *Scaling of fill sections.*
    - *Scaling of cut sections.*
    - *Configuration of the cut slope (slope, berms and retaining walls).*
    - *Maximum height of cut sections in the axis.*
    - *Configuration of the fill slope (slope, berms and retaining walls).*
    - *Maximum height of fill sections in the axis.*
    - *Excavatability.*
    - *Slope protection.*
    - *Definition of the roadbase layers of the type section.*

  - Geotechnics of Tunnels:
    - *Rock Mass Rating (RMR).*
    - *Type-cost.*
    - *Excavation methods.*
    - *Specific treatments.*

  - Geotechnics of Structures:
    - *Foundations in viaducts and bridges.*
    - *Foundations in crossings and minor construction works.*
    - *Excavation procedure.*
    - *Presence of water.*

- <u>Environmental variables</u>:

  - Protection areas:
    - *As many variables as classifications are created by the user. For example, Special Protection Areas, Biosphere Reserve, Natural Parks, etc.*

  - Evaluation of fauna:
    - *As many variables as classifications are created by the user. For example, Mammals, Birds, Invertebrates, Species in danger of extinction, etc.*

  - Evaluation of flora:
    - *As many variables as classifications are created by the user. For example, Species of trees, bushes, etc.*

  - Evaluation of soils:
    - *As many variables as classifications are created by the user. For example, farming land, karstic soils, etc.*

- Hydric and hydrogeological interactions:
    - *Areas of public hydraulic domain (including lakes or reservoirs). The user can include different classifications: river beds, streams, permanent watercourses, etc.*
    - *Angle of maximum crossing of water marks.*
    - *Passage clearance.*
    - *Aquifer (also with one or several classifications).*

- Perceptual Environment:
    - *Areas of Landscape Value (several classifications).*
    - *Visual fields of interest.*

- Permeability for the passage of fauna:
    - This refers to areas that require wildlife corridors at certain distances (tunnels and structures).

- <u>Climatic variables:</u>

    - Areas of strong frost
    - Shady areas
    - Areas of frequent storms
    - Areas of heavy rainfall
    - Areas of frequent snowfall
    - Areas of strong winds
    - Areas of frequent fog

- <u>Socio-economic variables:</u>

    - Primary sector areas
    - Secondary sector areas
    - Tertiary sector areas

- <u>Patrimonial variables:</u>

    - Public Land
    - Urban Land
    - Building Land
    - Non-Building Land
    - Archaeological sites (different classifications as created by the user, for example, Caution Areas, Places of Cultural Interest, etc.)
    - Areas of Special Interest
    - Crossing of farm tracks:
        - *Type of farm track*

    - Crossing of infrastructures:
        - *Crossing of linear infrastructures (roads, railways, channels, electric and telephone lines, etc)*
        - *Requirement of overpasses in linear infrastructures*

- *Areas occupied by public infrastructures (reservoirs, electrical substations, etc.)*
- *Mining or quarrying exploitations*

- Structures:

  - *Type-cost*

3. Determining variables and qualitative variables

All the variables are implemented as determining variables if the user bans the route from passing through areas with a specific value in the entry of a variable.

However, by default the program only considers specific variables for the configuration of alternatives in the different algorithms. These are known as determining variables. In turn, these variables are also qualitative, because they are used to calculate the value of the alternatives.

In the following table is a summary of the classification of the variables:

Groupe	Variable	Condition	Qualitative

Geomorphologic V.	Height above sea level	x	
	Clinometry	x	
Geotechnical variables Earthwork	Geotechnical risks	x	
	CBR		x
	Horizontal stability of the land	x	x
	Use of excavated materials		x
	Scaling of fill section		x
	Scaling of cut sections		x
	Setting up of cut slope	x	x
	Setting up of fill slope	x	
	Max. heights axis cuttings	x	
	Max. heights embankments	x	
	Excavatability		x
	Slope protection		x
	Roadbase layers	x	
Variables Géotechniques Tunnels	RMR		x
	Type-costs	x	
	Methods of excavation		x
	Specific treatments		x
Variables Géotechniques Structures	Foundations in viaducts		x
	Foundations in crossings		x
	Excavation procedure		x
	Presence of water		x
Mur	Volume of walls		x
V. Environnementales	Protection areas		x
	Evaluation of fauna		x
	Evaluation of flora		x
	Evaluation of soils		x
	Public hydraulic domain		x
	Angle crossing DPH		x
	Clearance over stream		x
	Aquifer		x
	Areas of landscape value		x
	Visual fields of interest		x
	Permeability of infrastructures		x
V. Climatiques	Areas of strong frost		x
	Areas of shade		x
	Areas of frequent storms		x
	Areas of heavy rainfall		x
	Areas of snowfall		x
	Areas of strong winds		x
	Areas of frequent fog		x
V. Socioéconomiques	Primary sector areas		x
	Secondary sector areas		x
	Tertiary sector areas		x
V. Patrimoniales	Public land		x
	Urban land		x
	Building land		x
	Archaeological sites, cult. int.		x
	Areas of special interest		x
	Type of farm track crossing		x
	Type of infrastructure crossing		x
	Require multilevel crossing		x
	Areas public infrastructures		x
	Mining or quarrying infrastructures		
V. Structures	Type-costs	x	

Table 2-1. Classification of variables

In addition to the GIS variables there are other qualitative variables that have to be taken into account: those needed to value the quality of the route, as well as those related to the investment that each alternative requires and its feasibility.

In the following sub-chapters, each of the variables of the GIS is analysed.

The user can select the desired variables for the subjective analysis of the different alternatives that are being evaluated.

TADIL SOFTWARE
TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES

GEOGRAPHICAL INFORMATION SYSTEM

SUB-CHAPTER 2. GEOMORPHOLOGIC VARIABLES

0. Introduction

This chapter describes the geomorphologic variables, how they are inserted, treated and processed.

As mentioned in the previous chapter, these variables determine the calculation of the route alternatives.

1. Geomorphologic variables

The geomorphologic variables that are implemented in the program are as follows:

- Height over sea level (metres above sea level), given by the land cartography.
- Clinometry: maximum slope of the terrain acceptable for a route (%).

Both of these variables determine the initial configuration of the route alternatives, although their impact is implemented in different ways. In the case of the variable maximum slope of land, the software includes a function that allows displaying areas with a higher slope than that specified by the user, allowing him to create banned areas. Similarly, the variable maximum slope of land is also included in each of the territorial Geotechnical files.

For this reason, the clinometry is a determining variable in the configuration of routes with the fan algorithm and the fan grid algorithm.

GEOGRAPHICAL INFORMATION SYSTEM

SUBCHAPTER 3. GEOTECHNICAL VARIABLES

0. Introduction

In this chapter the geotechnical variables are described, how they are implemented and their impact on the route.

1. Geotechnical variables

The geotechnical variables have the highest impact on the drafting of an infrastructure.

As mentioned earlier in informative studies, the impact of crossing a geotechnical area is automatic. In other words, the characteristics of the type section are automatically assigned according to the geotechnical characteristics of each cross section, as opposed to other drafting programs. This feature is applied dynamically to the fan so that, in the study of alternatives, the impact of the geotechnical variables is considered over the total cost of the infrastructure. This constitutes an exceptional qualitative feature in the route search.

The geotechnical variables are divided into conventional sections in cut or fill sections, viaducts or tunnels.

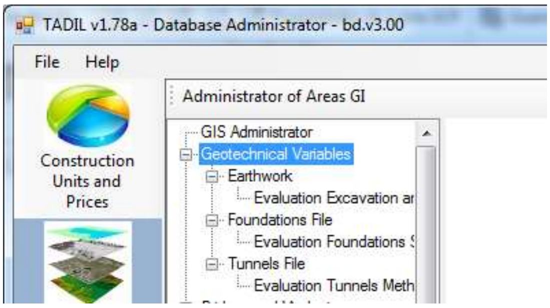


Image 2-1. Software architecture of the selection of geotechnical variables.

- Geotechnics of Earthwork:
  - *Geotechnical risks*
  - *CBR / Classification of the Underlying Natural Soil*
  - *Excavated materials used in the construction work*
  - *Scaling of fill sections*
  - *Scaling of cut sections*
  - *Configuration of the cut slope (slope, berms and retaining walls)*
  - *Maximum height of cut sections in the axis*
  - *Configuration of the fill slope (slope, berms and retaining walls)*
  - *Maximum height of fill sections in the axis*
  - *Excavatability*

- *Slope protection*
- *Definition of the roadbase layers of the type section (in the case of roads)*

○ Geotechnics of Tunnels:

- *Rock Mass Rating (RMR)*
- *Type-cost*
- *Excavation methods*
- *Specific treatments*

○ Geotechnics of Structures:

- *Foundations in viaducts and bridges*
- *Foundations in crossings and minor construction works*
- *Excavation procedure*
- *Presence of water*

Next we will describe each of the abovementioned variables in groups.

1.1. Geotechnical variables of earthwork

The user enters the variables in order to define a general file that corresponds to the predominant material. It will be applied by default to the whole cartography and to the specific files in areas with a smaller surface.

The user will be able to edit the files conveniently in the Edit Menu, create new ones or remove them.

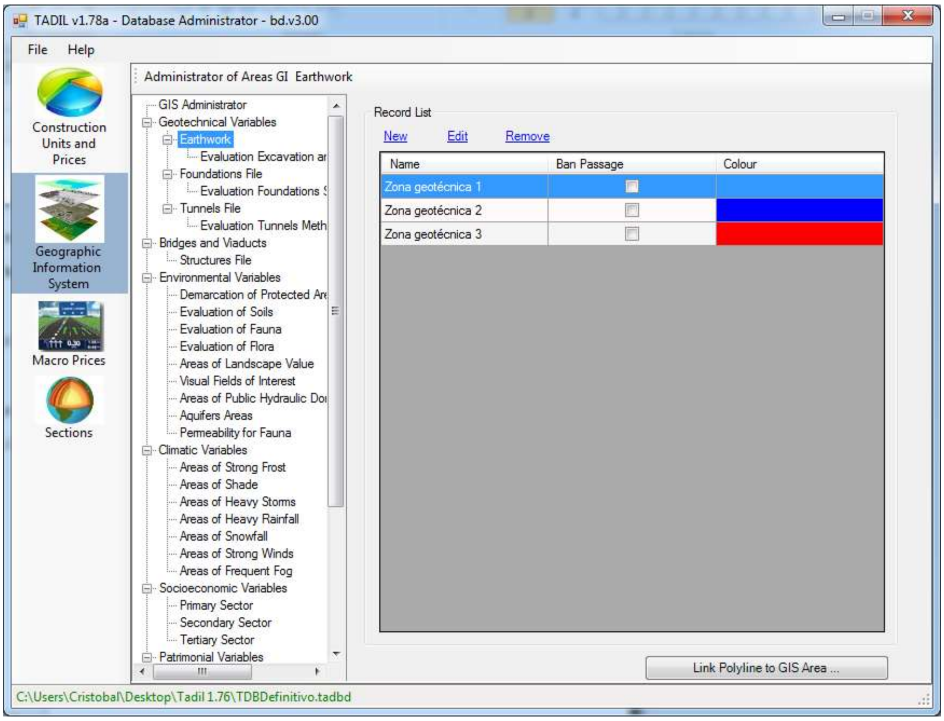


Image 2-2. Software architecture of the selection of a general or specific file, or file edition.

The general file and the specific file have the same structure, as can be seen in the images.

It is worth mentioning that **the program does not only consider geological variables**, but also geotechnical variables with an influence in the configuration of the type section.

When the user wants to create a classification based on ***geological criteria*** this can be done in the edition of Geotechnical files by designating the geological group that the defined lithological group belongs to.

The name of a geological group can be assigned to each geotechnical file, as well as a specific colour. The user, for instance, can give the same colour to all the lithological groups that belong to the same geological group. Therefore, an area of study can have eight different lithological groups that are included in five geological areas.

Each time a file is created, the corresponding polyline needs to be selected so that it is reflected on the project. Once it is designated, the user can save it with a chosen name.

In turn, the removal of the files entails the removal of the corresponding polylines that were assigned.

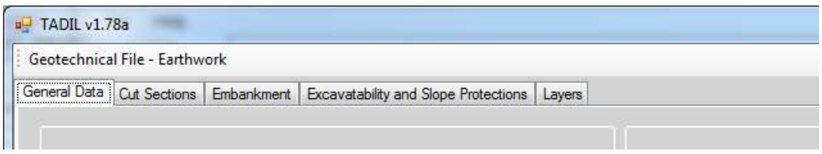


Image 2-3. Software architecture of the edition of the geotechnical file. Sub-menu structure.

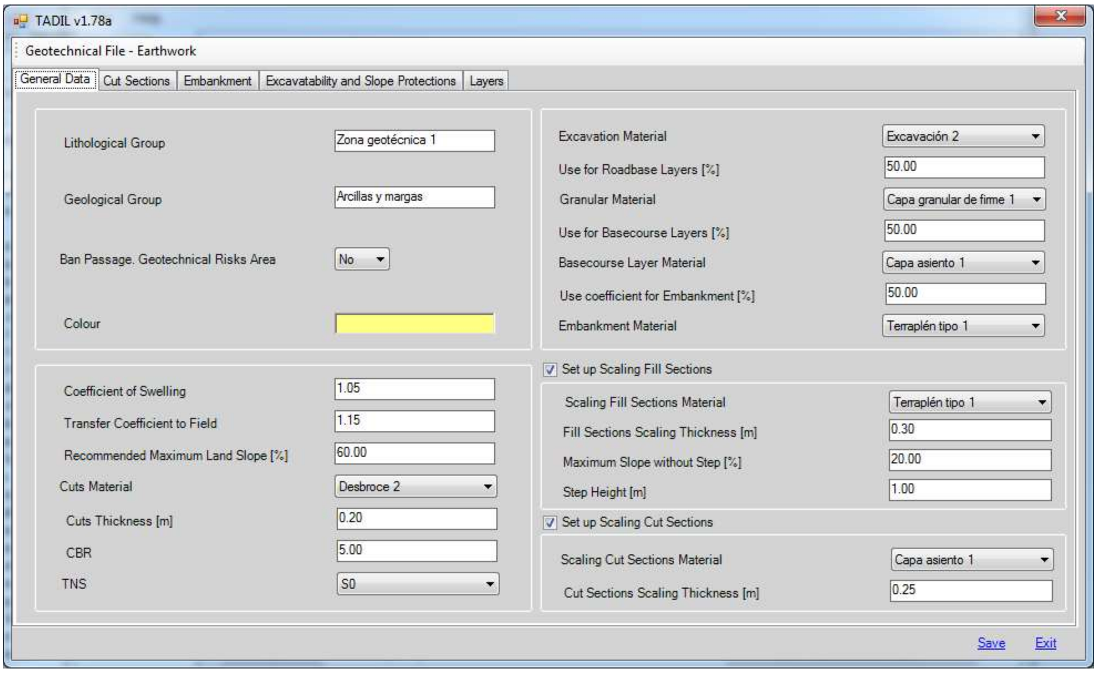


Image 2-4. Software architecture of the geotechnical file. General information.

The first variable considered in the geotechnical file is “Geotechnical risks area, do not cross”. This variable defines the areas through which the infrastructure should not cross due to different reasons. When this option is enabled, it is not necessary to input the rest of the information.

The variables Transfer Coefficient to Field and Coefficient of Swelling are used for obtaining the final budget of the infrastructure, and consequently for obtaining the results of profitability (Budget and Net Present Value). They allow an adequate evaluation of the earthwork balance.

The variable “Maximum slope of the terrain” is used for creating banned areas in places with little possibility of accepting routes due to their steep slope.

The California Bearing Ratio (CBR) value is a qualitative variable, and the value of the Underlying Natural Soil has an informative character. The program establishes by default the following types of Underlying Natural Soil and CBR which are common in most national regulations.

- Inadequate soil.
- Marginal soil.
- Tolerable soil.
- Adequate soil.
- Selected type 2.
- Selected type 3.
- Selected type 4.
- Natural gravel. NG
- Rock.
- Rockfill.
- Quarry-run fill.
- Soil stabilised on site.

The CBR is a percentage, so its value is between 0 and 100.

Abbreviations are designated for the Underlying Natural Soil. They are standardised in most of the regulations and they allow identifying the general characteristics of the **lithological material**.

The relationship between groups of the Underlying Natural Soil and the CBR are described in the following chart:

Symbol	Designation of material	Complementary prescriptions for their use in	
		Core	Base courses
SIN	Inadequate Soil	Cannot be used	Cannot be used
S00	Marginal Soil	Special study. Cannot be used in floodable areas	Cannot be used
S0	Tolerable Soil	CBR ≥ 3 Swelling (1)< 3% Cannot be used in floodable areas	Cannot be used
S1	Adequate Soil	CBR ≥ 5 Swelling (1)< 3% Except in floodable areas with <1%	CBR ≥ 5 Swelling (1) zero Can only be used in soils SIN,S000 or S0
S2	Selected Soil Type 2	CBR ≥ 10 Swelling < 1%	CBR ≥ 10 Swelling (1) zero
S3	Selected Soil Type 3	CBR ≥ 20 Swelling (1)< 1%	CBR ≥ 20 Swelling (1) zero
S4	Selected Soil Type 4	CBR ≥ 20 Swelling (1)< 1%	CBR ≥ 40 Swelling (1) zero
S-EST1	Soil Stabilised On Site Type 1	Lime or cement ≥ 2% and CBR after 7 days ≥ 6	
S-EST2	Soil Stabilised On Site Type 2	Lime or cement ≥ 3% and CBR after 7 days ≥ 12	

S-EST3	Soil Stabilised On Site Type 3	Compression resistance after 7 days ≥ 1.5 MPa and Cement ≥ 3%

Z	Gravel	According to Article 510 of the PG-3	
ROCK	Cut sections in rock	-	Regularization with concrete HM-20
P	Rockfill	According to regulations	Cannot be used in base courses
TU	Quarry-run fill	According to regulations	Cannot be used in base courses
(1) The swelling will be performed in an oedometer according to Norm UNE 103.601			

Tabla 2-2. TNS – CBR.

The percentage of excavated soil used in the construction work is also a qualitative variable that is taken into account in the definition of the earthwork balance and the budget. Similarly, the scalings are qualitative variables and they are also considered in the earthwork balance and the budget.

It is worth stressing the importance of anticipating in the management of the construction work an adequate use of the materials obtained from the excavations. The fewer borrow pits that are required, the more optimized the construction work will be. Consequently, this section plays a decisive role in the feasibility of the project, at least as an Informative Study.

For the management of materials, in the program the best materials obtained from the excavation can be used in any layer, as long as they are left over. For instance, there is an infrastructure that crosses a geotechnical area where excavations produce up to 12,000 m^3 of gravel. In the construction work only 4,000 m^3 are needed for the roadbase layers. The remaining amount can therefore be used in the base courses (instead of the selected soil). If there is more gravel left over, it would then be used to create the fill section, instead of using the adequate soil.

Likewise, if 20,000 m^3 of the selected soil is extracted from the site and only 15,000 m^3 is needed in the base courses, the remaining 5,000 would be used for creating the fill section. It could not be used in the granular roadbase layers because it would not comply with the technical requirements.

The program adjusts the use of the excavated materials by first completing the granular layers, which are the most expensive, then completing the base courses and, finally, completing the fill section, considering all the materials that can be obtained throughout the route, in the different geotechnical groups that are crossed.

GRANULAR LAYERS → BASE COURSES → FILL SECTION LAYERS

The user must therefore indicate the excavated materials that will be used in each of the groups of layers. To make the most of the excavated materials, they must match the ones designated in the section layers, in all of the geotechnical groups.

Therefore, the percentages of use of the excavated materials in each group of layers will have a value of increase. In other words, the percentage of usable excavated materials for fill sections is larger or equal to the percentage for base courses, and the percentage of usable excavated materials for base courses is larger or equal to the percentage for granular roadbase layers.

% Use of materials in fill sections ≥ % Use of materials in base courses

% Use of materials in base courses ≥ % Use of materials in granular roadbase layers

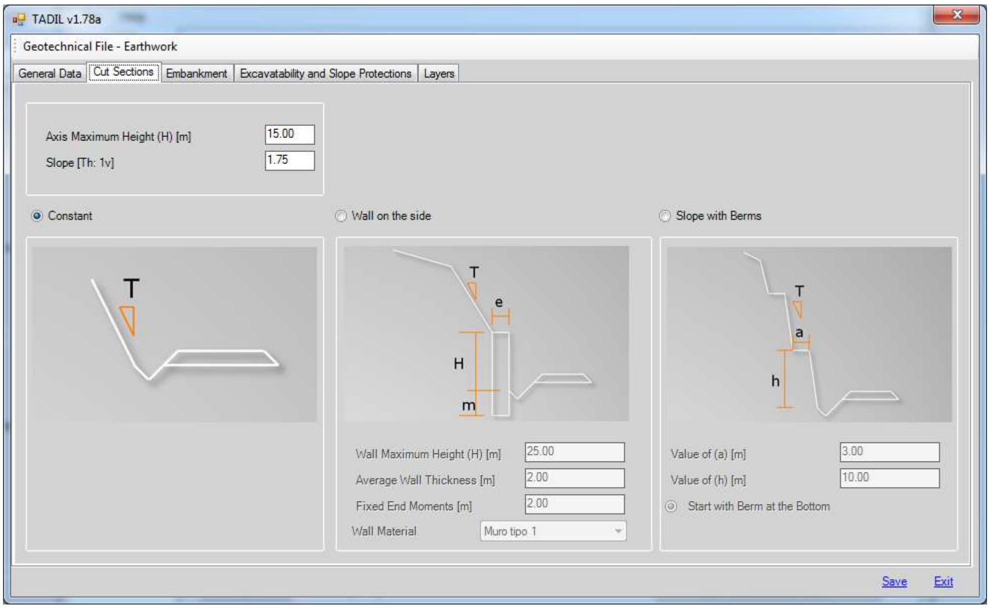
In general, the user can design a personal material management strategy. When designing an infrastructure, it is common to find areas with very good materials alternating with areas that have very bad materials. It is convenient in these cases to designate the materials obtained from the geotechnical areas which have the best materials for the creation of the layers (granular roadbase layers, base courses and fill sections).

The materials designated in each layer and fill section are assigned a price from the database, depending on whether they are obtained from the excavations on site or they are borrowed. In the same way, two prices will be considered for the excavations: one for the amount of material used in the construction work and another for the landfill material.

Regarding the configuration of cut and fill sections:

- The height of the slope is limited by the maximum height of the axis in the cut and fill sections. It can be given to a geotechnical group or to the totality of the construction work.

- All the variables influence the definition of the route alternatives. Moreover, they will also determine the budget of the infrastructure.



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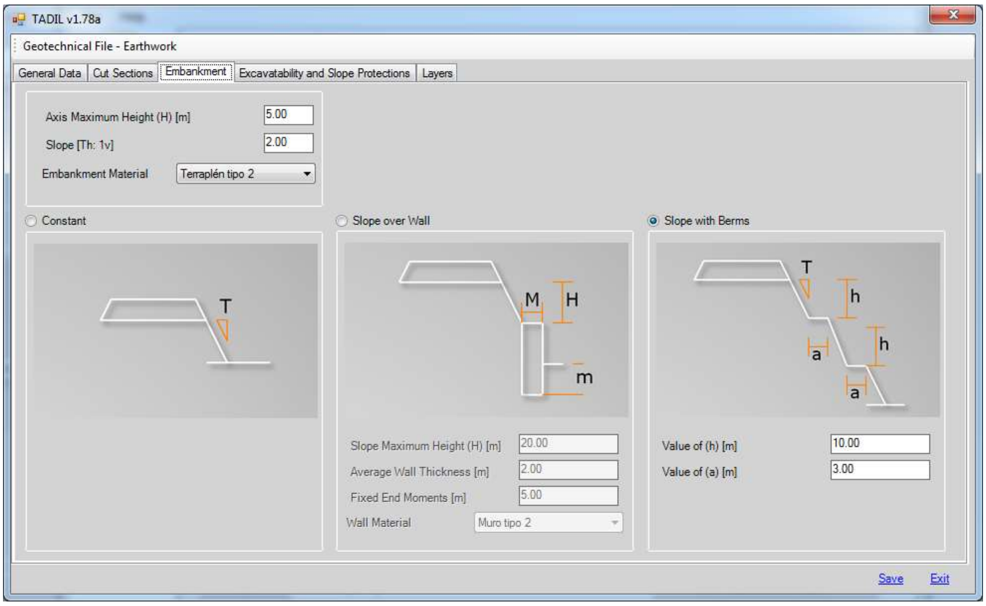


Image 2-5. Slope file.

The following three possibilities are considered for cut and fill sections:

- Continuous slope
- Slope over wall
- Slope with berms

Regarding excavatability and the protection of slopes in each geotechnical group, it must be noted that these variables have a subjective value.

The score is better if the excavation is easier and there are less requirements regarding slope protection.

In the following chart, we can see the different options.

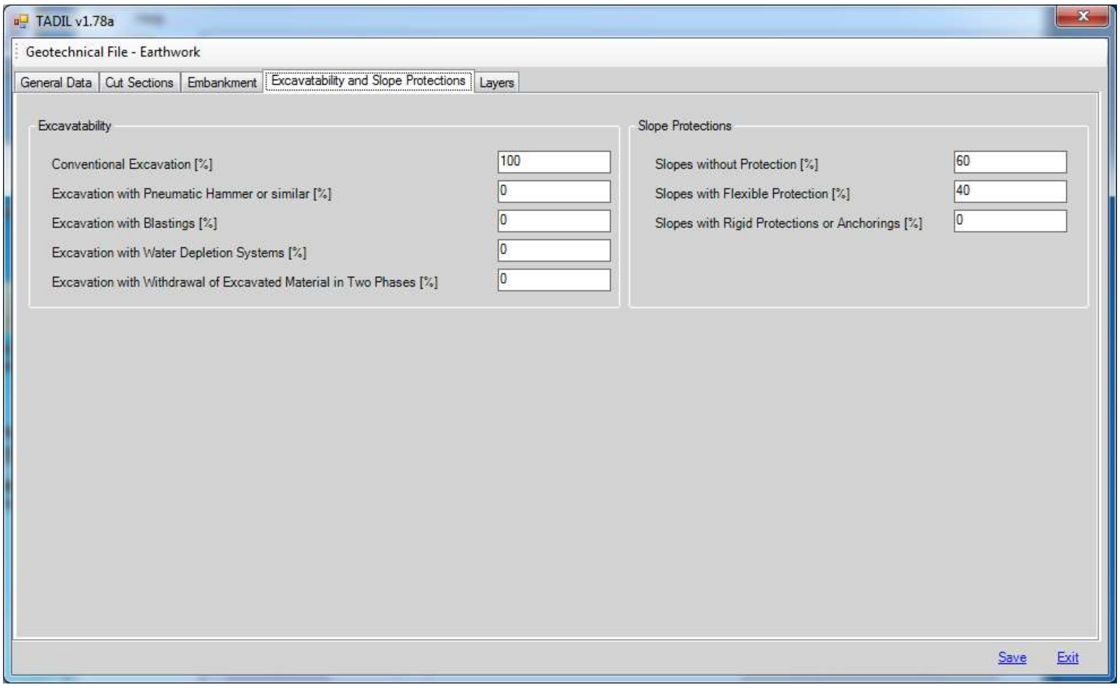


Image 2-6. Options for defining excavatability and slope protection.

Finally, it must be pointed out that, in the case of roads, the pavements are defined according to their geotechnical group.

In the Geotechnical File Menu, the user must include the roadbase layers and the base courses.

Moreover, the user can copy the layers of the carriageway onto the hard shoulder.

In the diagram of the type section layers, the difference in thickness between the roadbase layers and the hard shoulder is completed with the material that is directly below, in the base course or the fill section.

The layers are inserted from top to bottom.

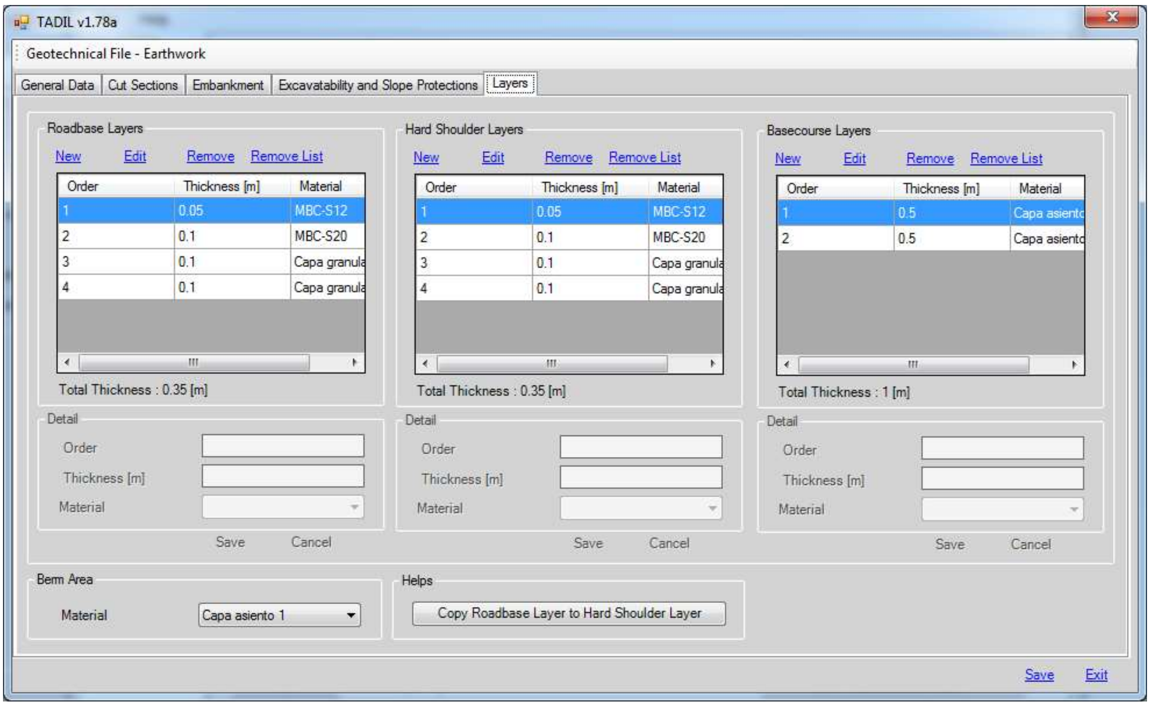


Image 2-7. Input of roadbase layers.

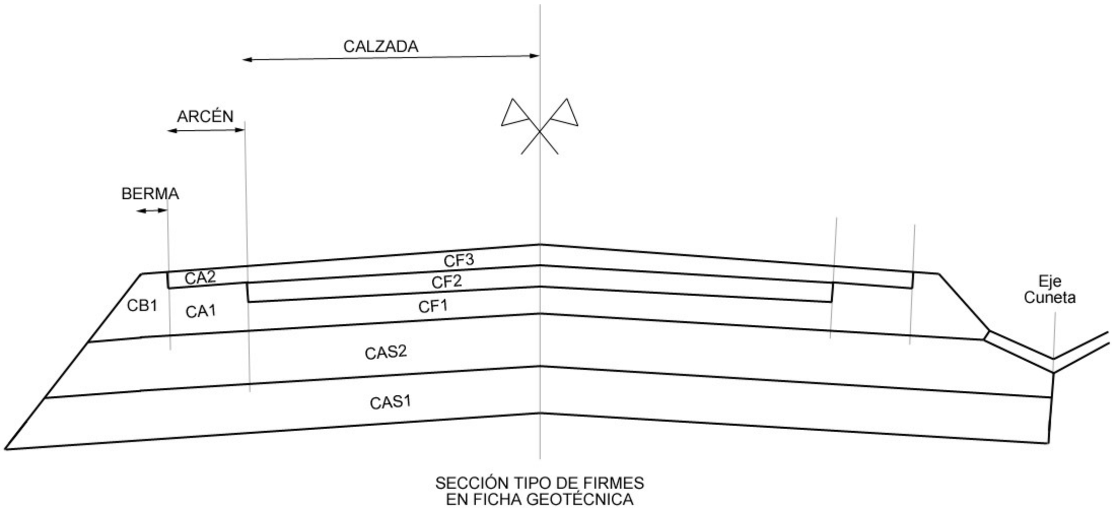
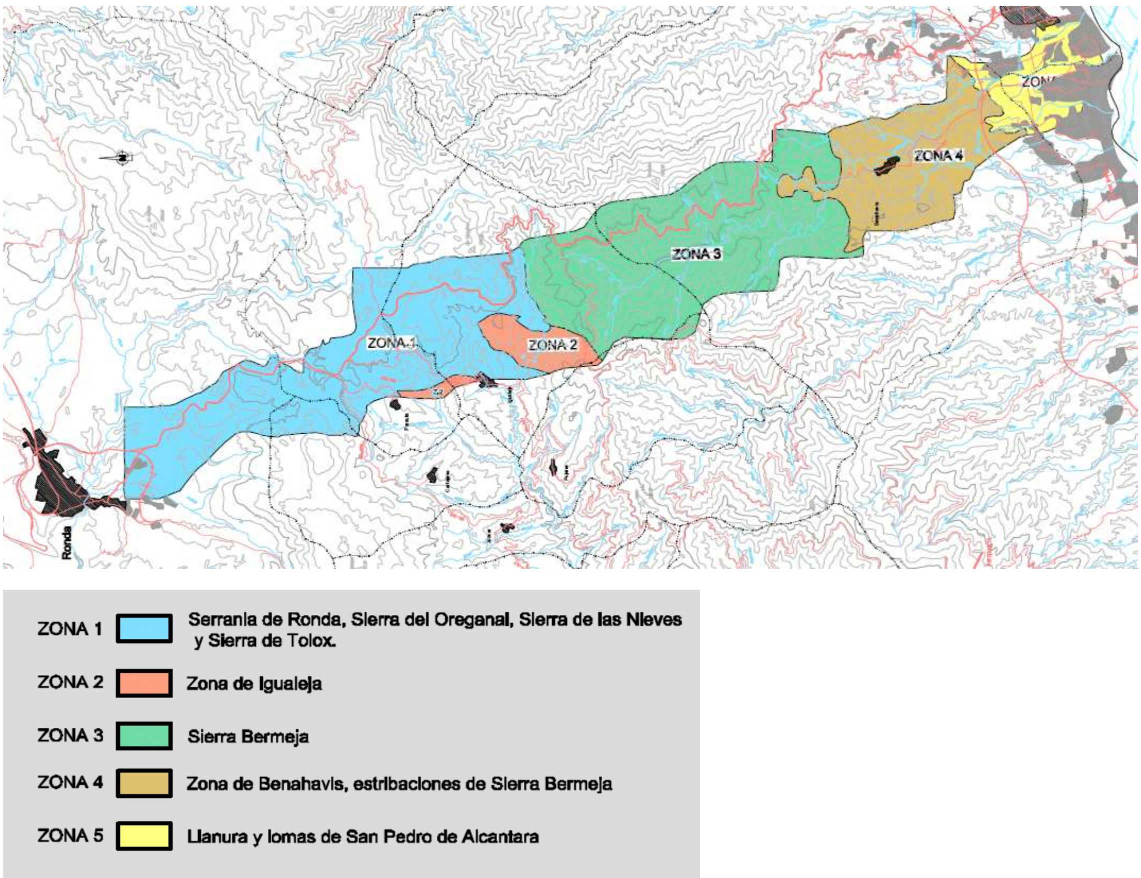


Chart 2-1. Conventional section of types of road surface.



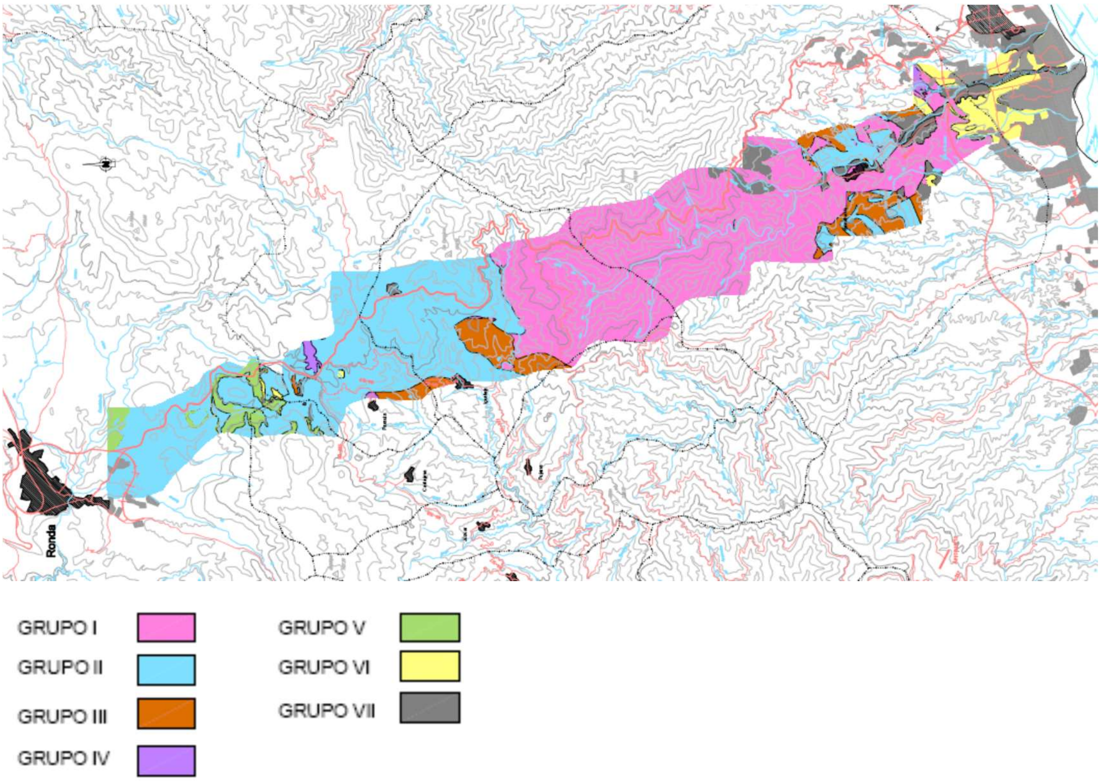


Image 2-8. Example of definition of eight geotechnical areas included in five geological groups.

1.2. Geotechnical variables for tunnels

In order to define the geotechnical variables for tunnels, the following parameters are analysed:

- Rock Mass Rating (RMR)
- Type-cost
- Excavation methods
- Specific treatments

As in the case of the Geotechnical files of earthwork, one general file can be created and specific files can be added.

The names or lithological groups can match those described in the geotechnics of earthwork, or new ones can be created.

In the file, the user can simply indicate the prohibition of inserting tunnels in a specific area of the territory. This is a determining feature in the configuration of the routes, both for the fan algorithm and for the fan grid algorithm.

The type of tunnel established in a particular area corresponds to one of the construction units, with the corresponding price per kilometre, included in the Construction Units and Prices Database. When selecting a type, the budget is calculated with the price assigned to that type.

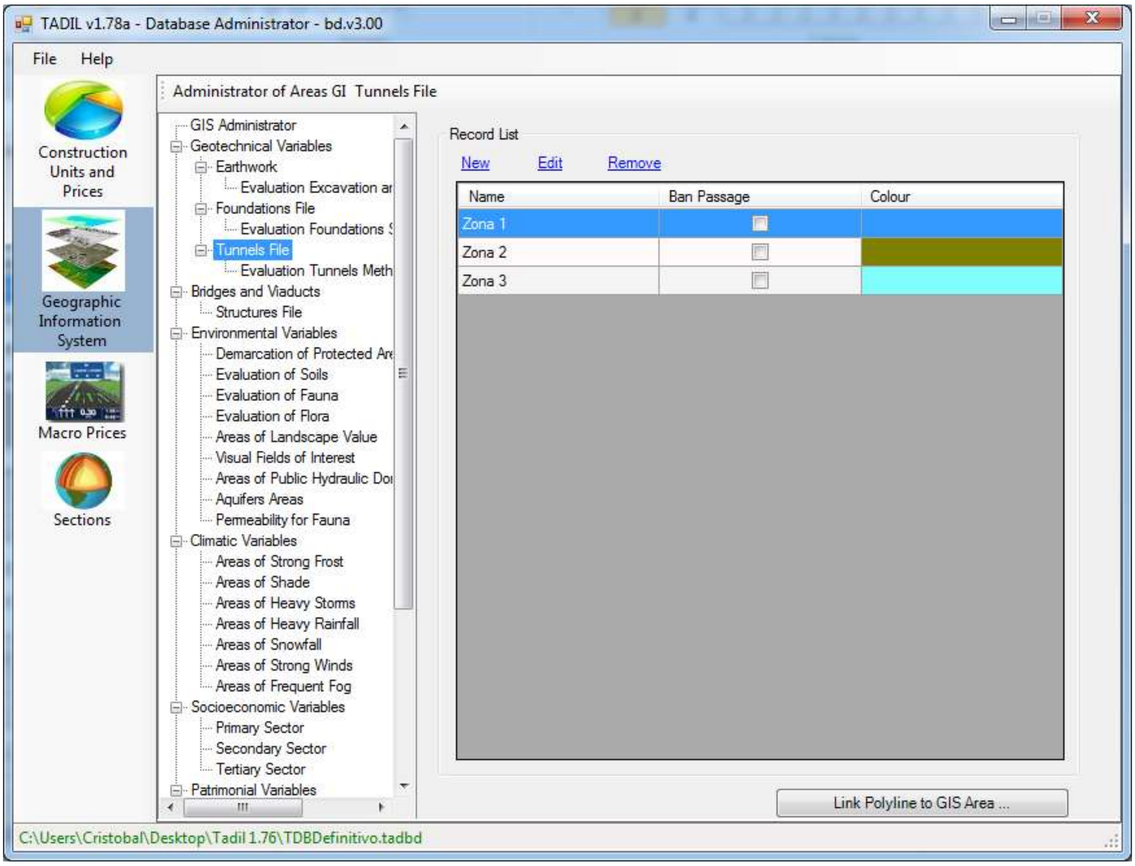


Image 2-9. Software architecture of file edition.

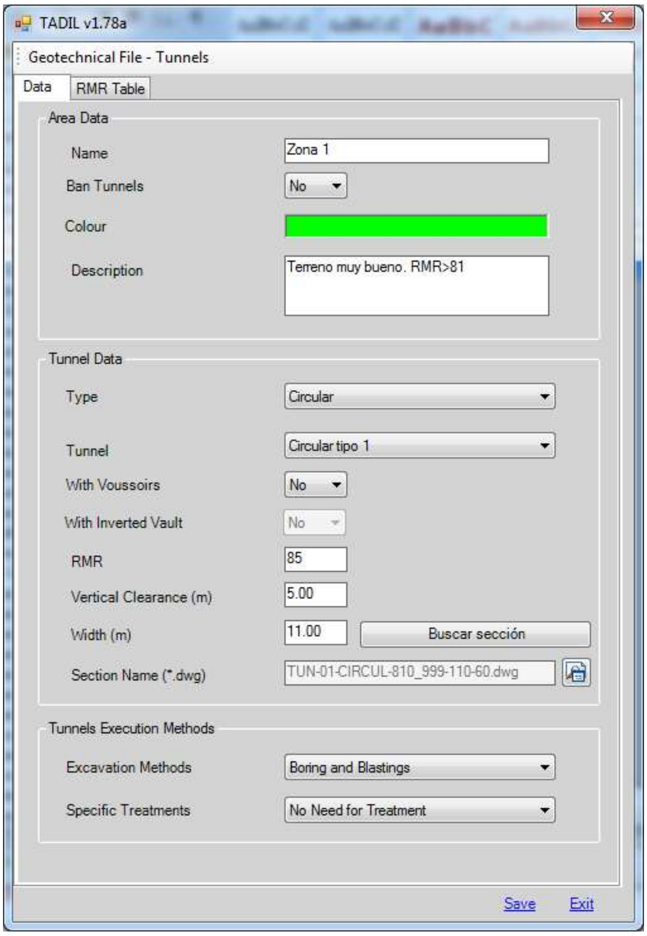


Image 2-10. Geotechnical file for tunnels.

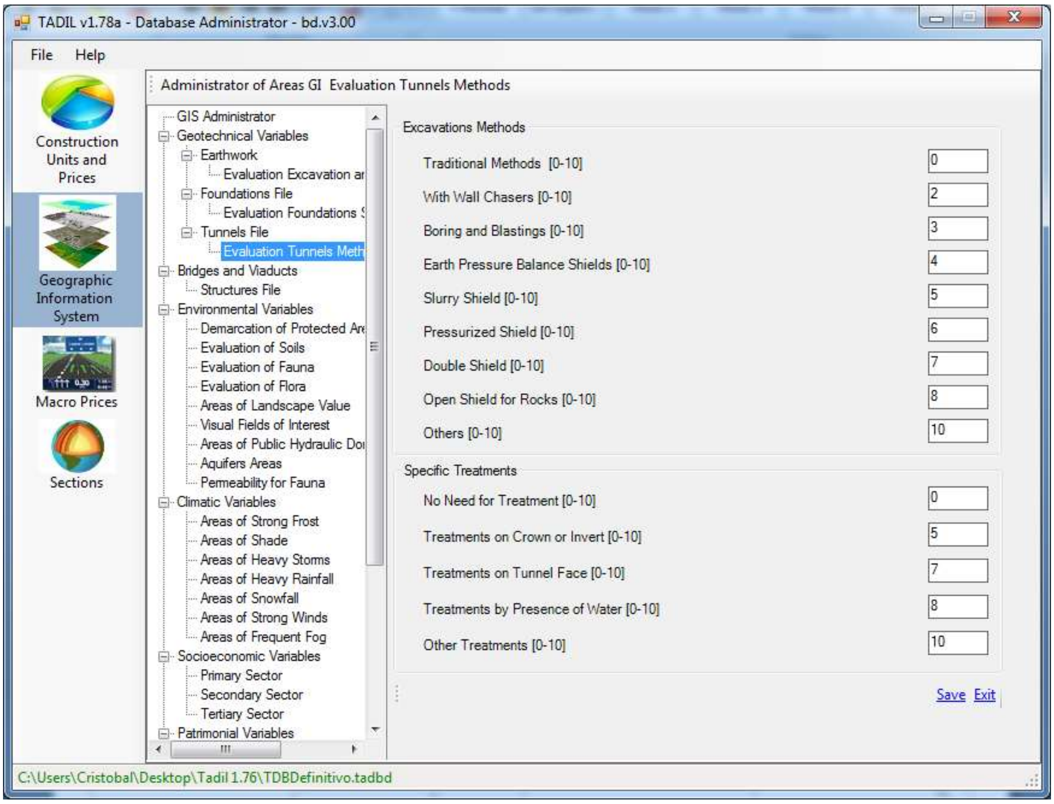


Image 2-11. Excavation methods and specific treatments.

The information on the vertical clearance and extra clearance width of the platform can be used to create the cross section of the tunnel. The horizontal clearance is formed by the width of the platform specified by the user plus a minimum margin of 30 cm each side. The vertical clearance plus the horizontal clearance configure the rectangle of clearances.

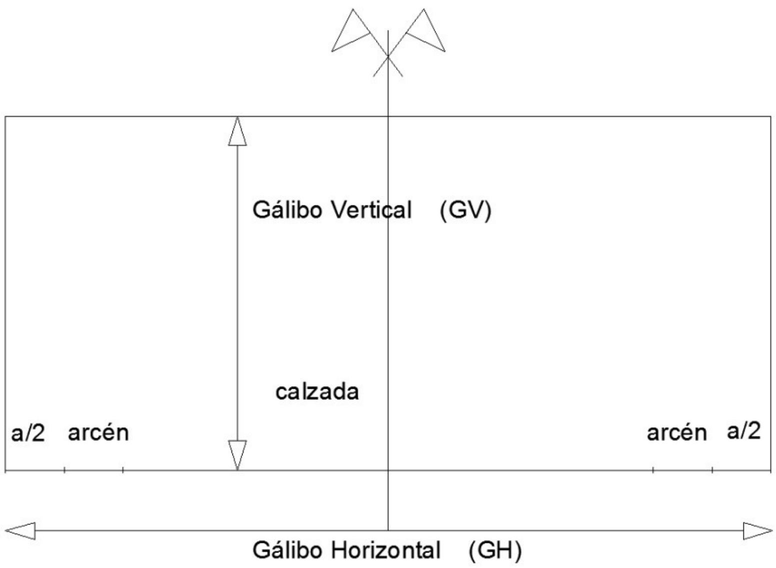


Image 2-12. Diagram of passage clearances in a tunnel, where "a" is the margin to be considered by the user.

Once the horizontal and vertical clearances have been defined, the user is suggested three geometries which are configured as follows:

Circular: In this case, the inside perimeter crosses the four points of the rectangle defined by the passage clearance.

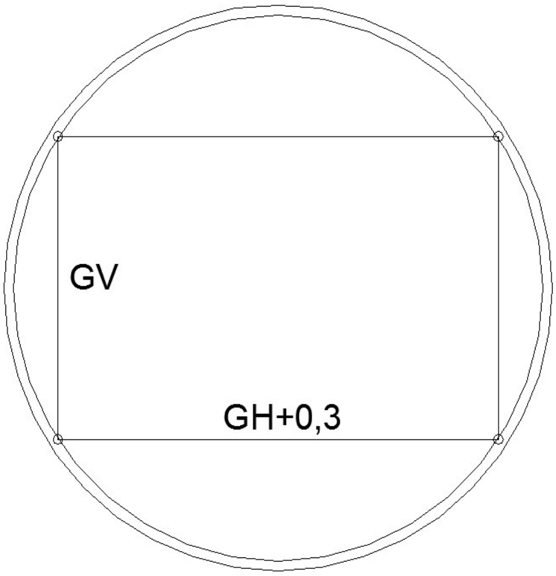


Image 2-13. Configuration of tunnel with a circular section

Horseshoe: In this case, the semicircular arch is situated above the passage clearance.

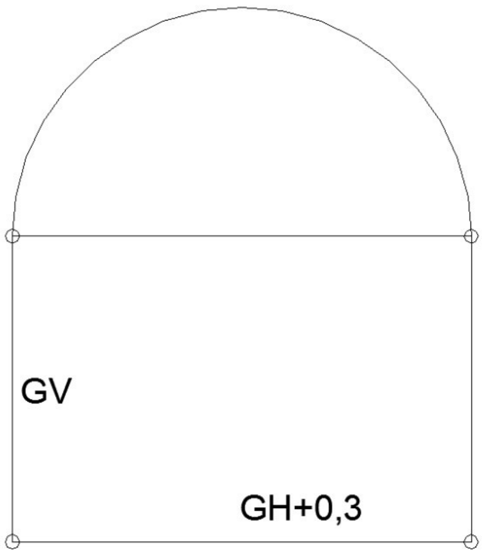


Image 2-14. Configuration of tunnel with horseshoe section.

Vault: The lower arches radiate from the opposite lower vertex of the clearance rectangle, and cross the upper vertex. The upper arch radiates from the centre of the clearance rectangle and crosses the two upper vertexes of the clearance rectangle.

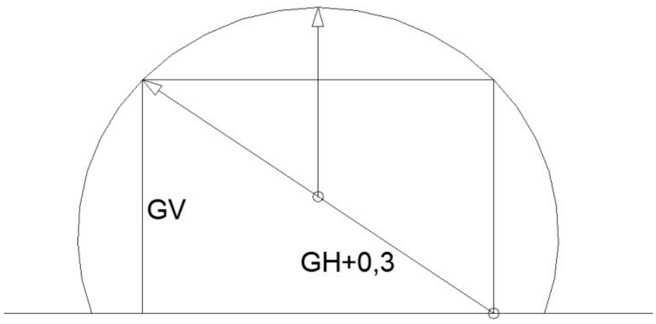


Image 2-15. Configuration of tunnel with vault section

The user can also select an inverted vault (only for horseshoe or vault sections).

Finally, the support and lining are defined according to the RMR value and the following table:

RMR	EXCAVATION	BOLTING	SHOTCRETE	TRUSSES
>81	Complete section. Feedrates of 3 m.	An occasional bolt.	Unnecessary or 5 cm for security reasons	No
61-80	Complete section. Feedrates of 1-1.5 m.	Local bolting in vault. L=2-3 m. S=2-2.5 m.	5 cm in vault. Possibly mesh.	No
41-60	Feedrate & bench excav. Feedrates of 1.5-3 m.	Systematic bolting. L=3-4 m. S= 1.5-2m.	5-10 cm in vault, 3 cm in pediment. Mesh in vault	No
21-40	Feedrate & bench excav. Feedrates of 1-1.5 m.	Systematic bolting. L=4-5 m. S= 1-1.5m.	10-15 cm in vault. 10 cm in pediment. Systematic mesh.	Light; S=1.5 m.
<20	Multiple stages. Feedrates of 0.5-1m.	Systematic bolting, (even in solepiece). L=5-6 m,S=1-1.5	15-20 cm in vault. 15 cm in pediment and 5 cm in front. Systematic mesh.	Heavy and closed; S=0.75

Table 2-3. Table of RMR.

According to the previous chart of RMR values, the program offers the possibility of incorporating the tunnel type section into each cross section, creating five groups with the following bolting and shotcrete features:

Group	Bolting	Shotcrete

1	Only occasionally	5 cm.

2	Local in vault. Average length = 3 m	5 cm.
3	Systematic. Av. Length = 4 m.	10 cm vault. 5 cm the rest.
4	Systematic. Av. Length =5 m.	15 cm vault. 10 cm the rest.
5	Intensive and in solepiece. Av. Length =6 m.	20 cm vault. 15 cm the rest.

Table 2-4. Support options represented in cross-sections.

The previous variables are used to design the cross section. The vault is differentiated from the rest of the tunnel as a support according to the following criteria:

- Circular section: the top 120º of the circle.
- Horseshoe section: the top arch.
- Vault section: the top arch and the top half of the bottom arch.

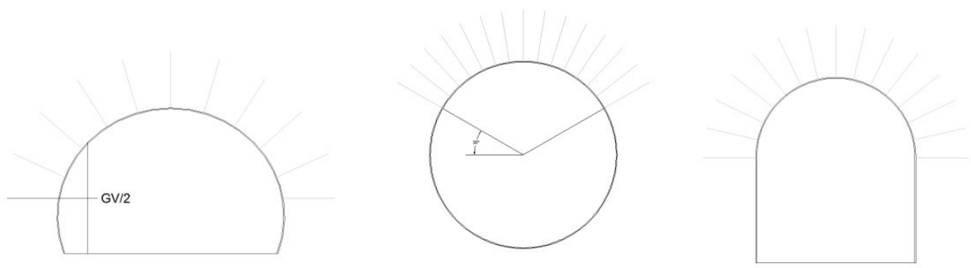


Image 2-16. Location of the top reinforcement area in the three types of tunnels

The user can choose the previous group depending on the selected RMR.

In this case, the support will be assigned as follows:

Group	RMR

1	81-100

2	61-80
3	41-60
4	21-40
5	0-20

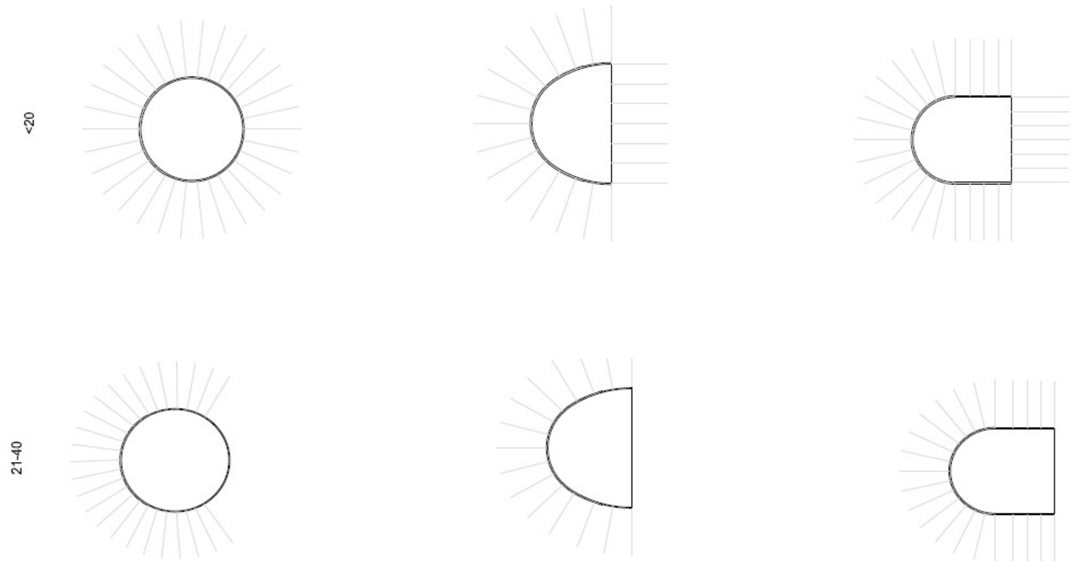
Table 2-5. Assignment of groups of support according to RMR.

All the previous information merely outlines the selected cross section. The user must consider whether to incorporate a section that best adapts to the project.

The type of tunnel required and its associated cost constitute a determining variable, considering that the high cost of the execution will be taken into account in the automatic route calculation algorithms.

Finally, it is worth mentioning that the procedures of excavation and the requirement of specific treatments are qualitative variables.

In the following page, we can see the lining diagrams for the different geometrical shapes that are included.



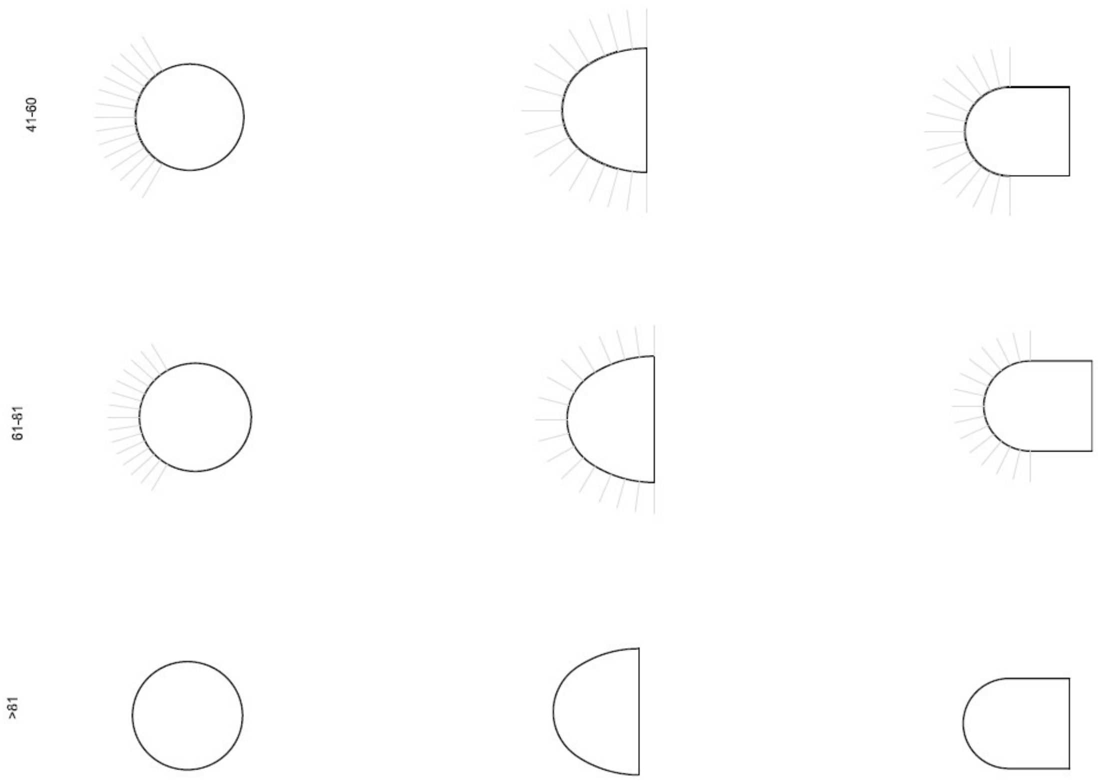


Chart 2-2. Diagrams of type section of tunnels according to geometry and RMR lining.

1.3. Geotechnical variables for structures

In order to define the geotechnical variables for tunnels, the following parameters are analysed:

- Foundations in viaducts and bridges
- Foundations in crossings and minor construction works
- Excavation procedure
- Presence of water

All the previous variables are qualitative. The influence over the total cost is determined in the Structures Menu, where a code is associated to a price indicated by the user.

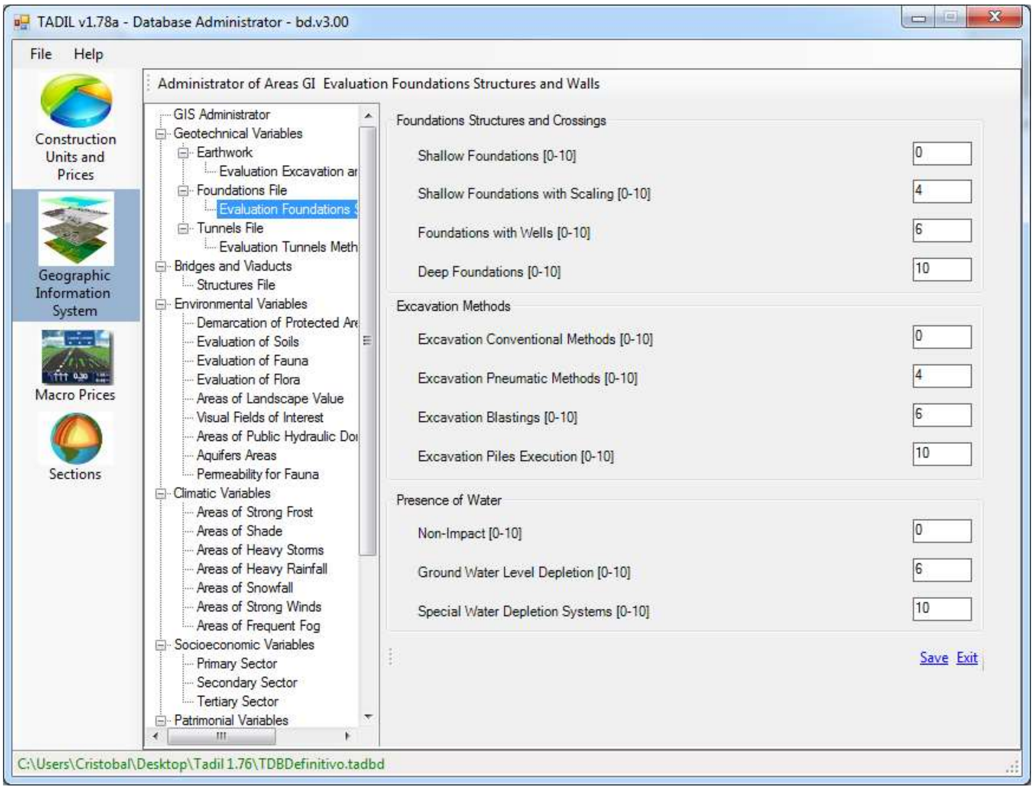


Image 2-17. Qualitative variables for foundations of structures.

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SUB-CHAPTER 4. ENVIRONMENTAL VARIABLES

0. Introduction

In this chapter, the environmental variables are described, as well as their implementation and their impact on the route.

1. Environmental variables

The environmental variables considered in this section are the following:

- Protection areas
- Evaluation of fauna
- Evaluation of flora
- Evaluation of soils
- Hydric and hydrogeological interactions:
  - Areas of public hydraulic domain (including lakes or reservoirs). The user can include different classifications: river beds, streams, permanent watercourses, etc.
  - Angle of maximum crossing of water marks.
  - Clearance over water lines.
  - Aquifer (with one or several classifications).

- Perceptual Environment:
  - Areas of Landscape Value (several classifications).
  - Visual fields of interest.

- Permeability for the passage of fauna:
  - This refers to areas that require wildlife corridors.

The general entry file for environmental variables allows selecting any of the previous groups.

Next is a description of each of the environmental variables.

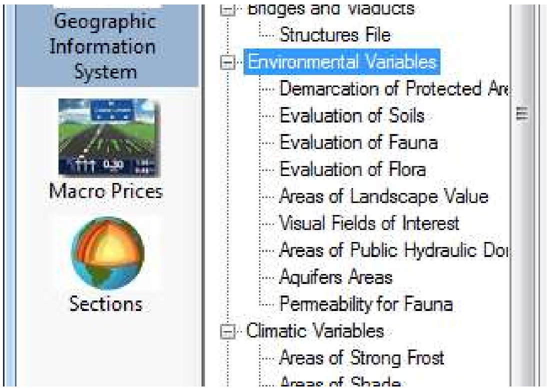


Image 2-18. Software architecture of the Environmental Variables Menu.

1.1. Protection areas

This variable, as most of the environmental variables, can be divided into several categories in accordance with the classifications determined by the user. Afterwards, the user must evaluate each each element of each category. Therefore, a common classification can be as follows:

- Special Protection Plans
- Atlas of Natural Areas
- Natural Parks
- National Parks
- Natura Network
- Places of Communitarian Interest
- Biosphere Reserve

In the following example, we can see a variety of possible classifications due to the rich natural environment.

Therefore, we can find Places of Communitarian Interest, Biosphere Reserves, areas belonging to the Special Protection Plan, areas included in the Atlas of Natural Areas, areas of the Natura Network (Special Protection Areas for the Conservation of Wild Birds), and Natural Parks.

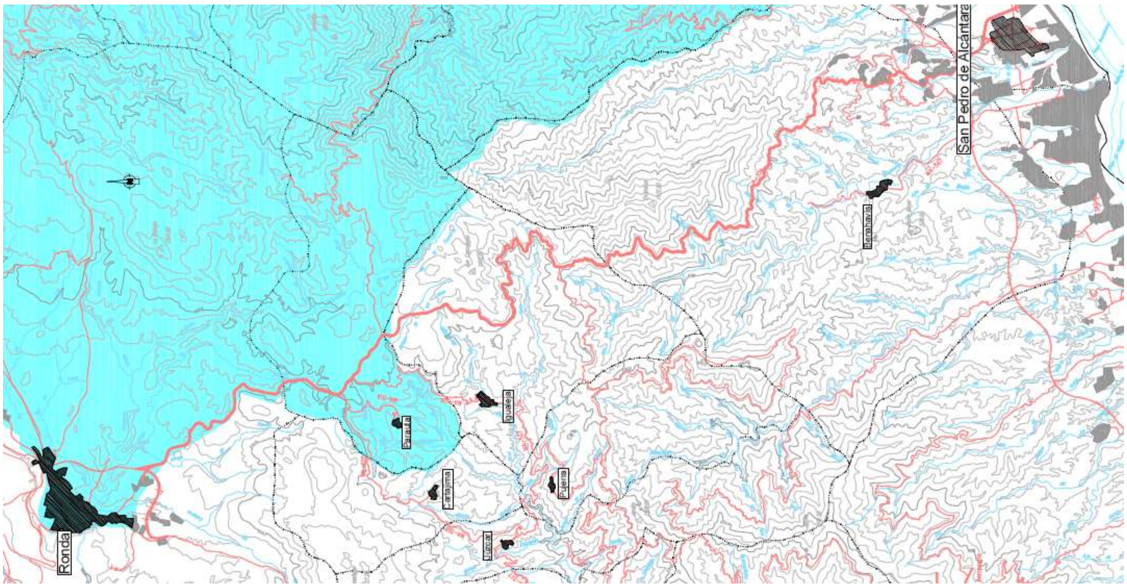
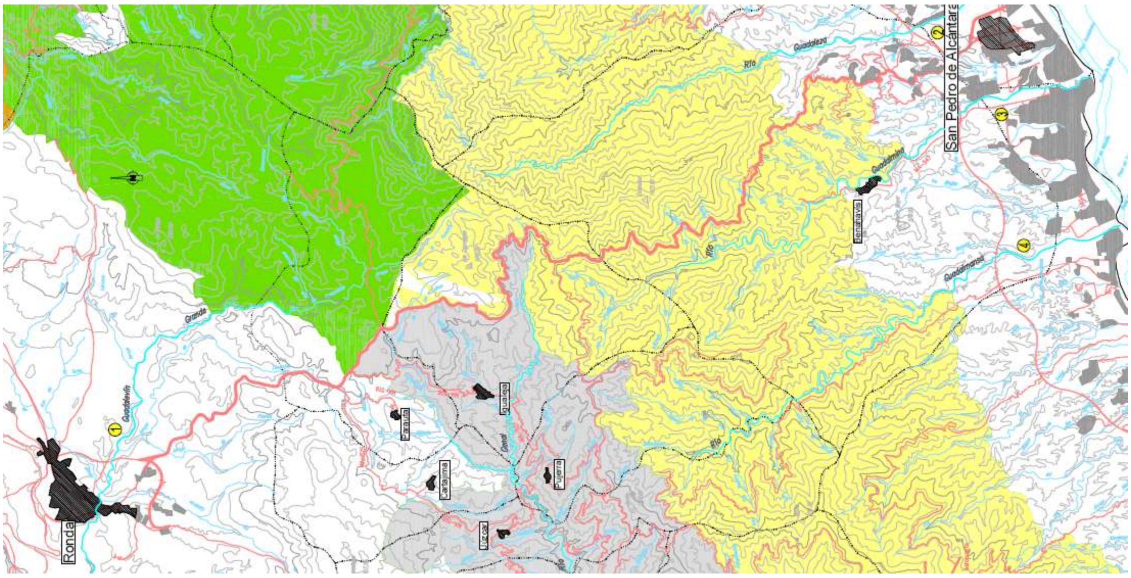


Image 2-19. Biosphere reserve.



LUGARES DE INTERES COMUNITARIO

- SIERRA DE LAS NIEVES
- SIERRA BLANQUILLA
- SIERRA BERMEJA Y REAL
- LOS REALES DE SIERRA BERMEJA
- SIERRA CRESTELLINA
- VALLE DEL RIO DEL GENAL
- FONDOS MARINOS DE LA BAHIA DE ESTEPONA

Image2- 20. Places of Communitarian Interest.

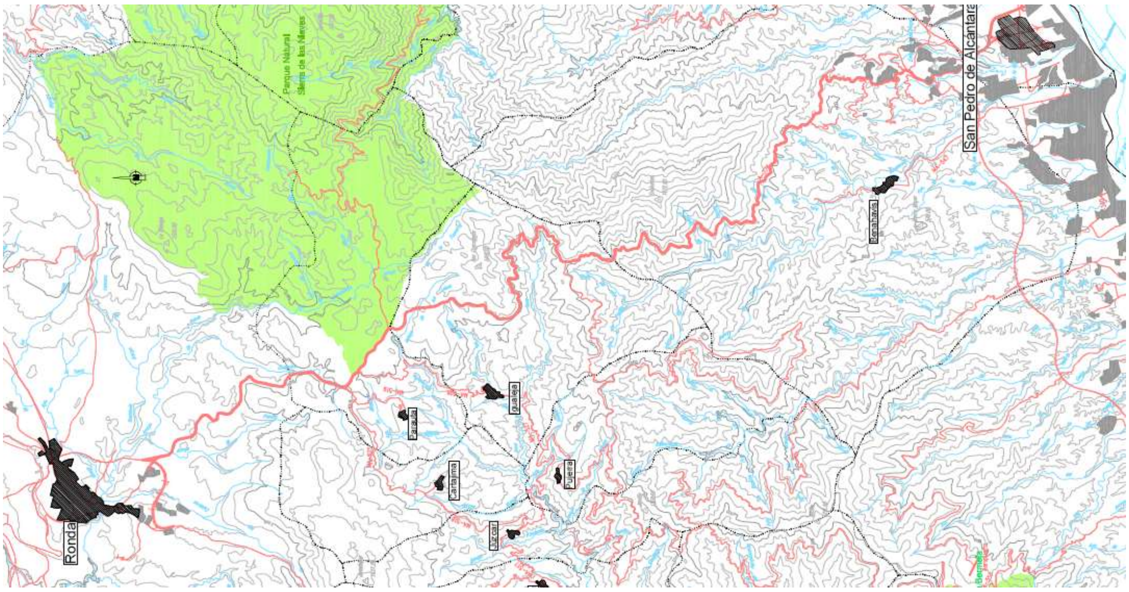
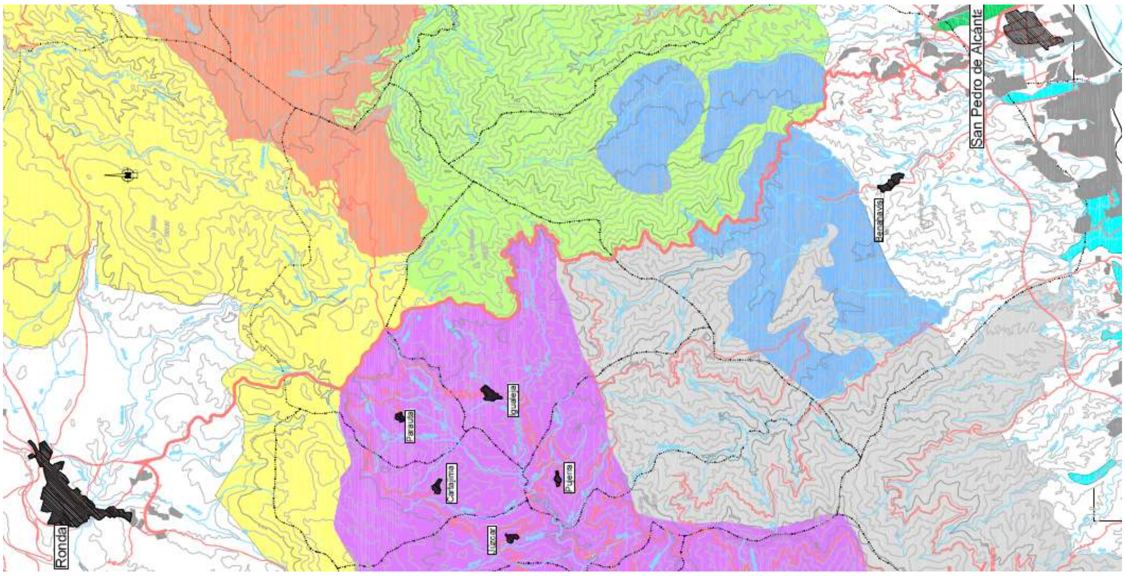


Image 2-21. Natural 2000 Network. Special Protection Area.



PLAN ESPECIAL DE PROTECCION DEL MEDIO FISICO
- CS-20 VALLE DEL GENAL
- CS-14 SIERRA OREGANAL - HIDALGA - BLANQUILLA
- PE-1 SIERRA DE LAS NIEVES
- CS-18 SIERRA REALPALMITERA-APRETADERAS
- PE-3 LOS REALES DE SIERRA BERMEJA
- AG-8 VEGA MARGEN DERECHA DEL RIO GUADAIZA
- CS-24 SIERRA BERMEJA
- HUERTAS DE ESTEPONA (PROTECCION CAUTELAR)
- MONTES DE BENAHAVIS (PROTECCION CAUTELAR)

Image 2-22. Special Protection Plan

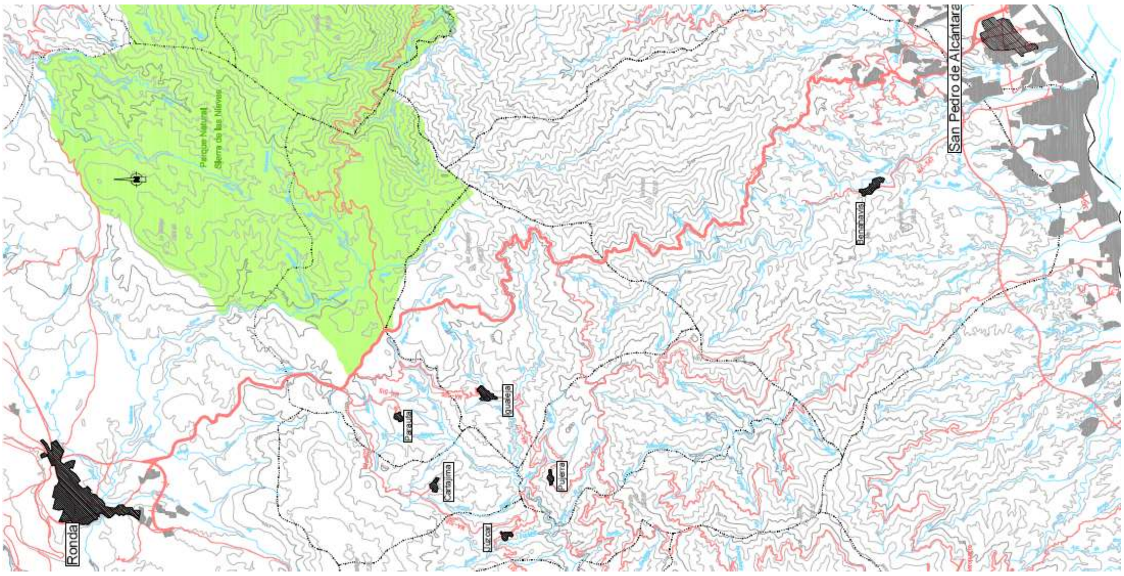


Image 2-23. Protected Natural Areas.

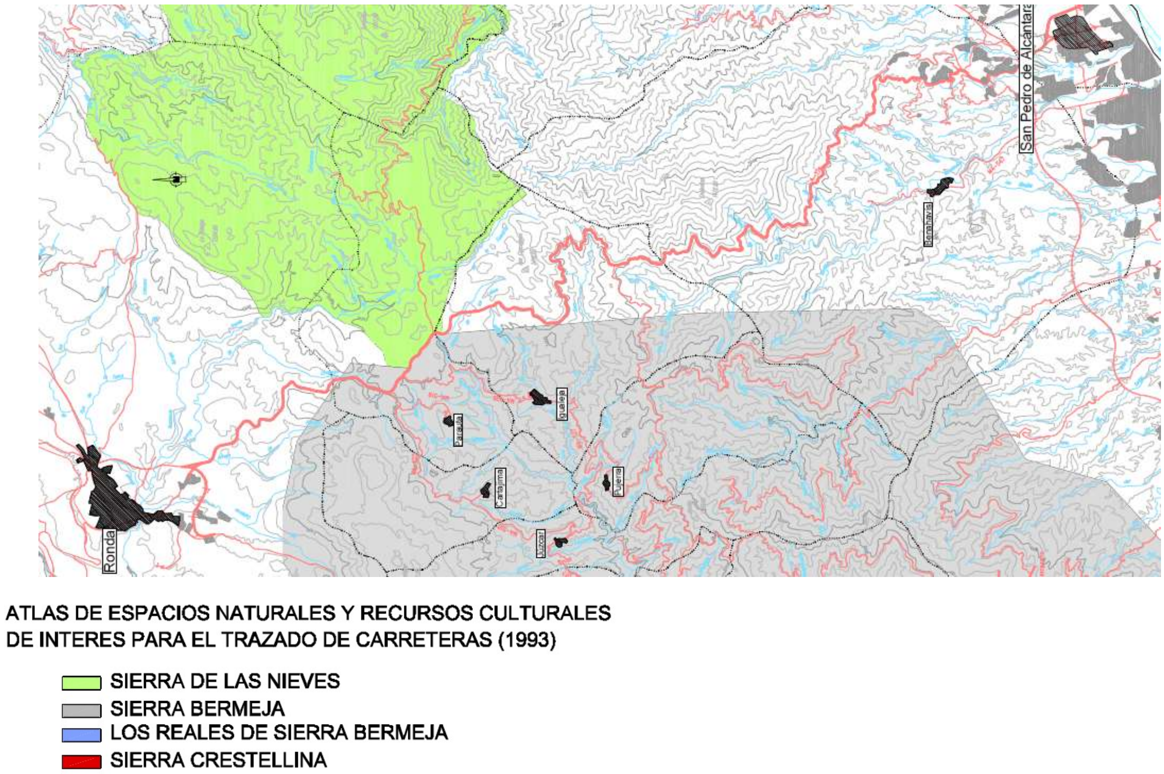


Image 2-24. Atlas of Natural Areas

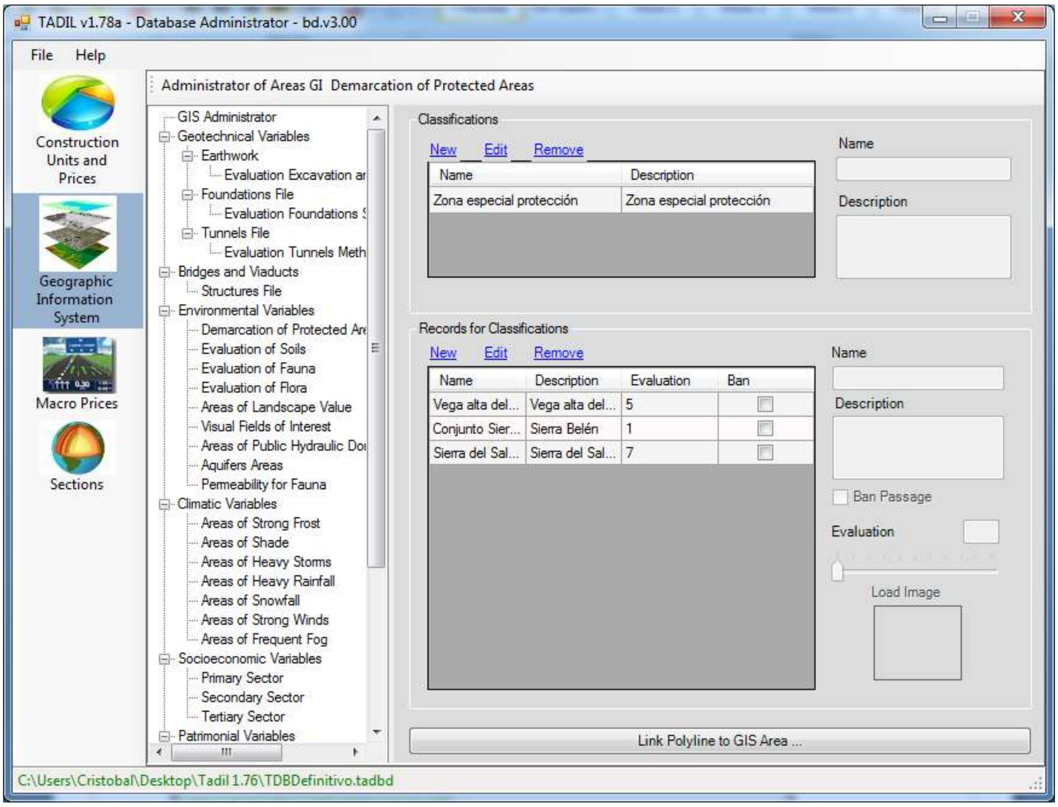


Image 2-25. Software architecture of the input of classifications and areas with evaluations.

Moreover, in the alternatives the banned areas can be indicated.

In each point, the final punctuation of the variable Protection Area will be the addition of the evaluations of each area belonging to the aforesaid point, with a maximum of 20. When the evaluation is higher, a value of 10 will be considered.

1.2. Fauna

Similarly, several classifications can be created for these variables. A common classification is as follows:

- protected mammals
- protected invertebrates
- protected birds
- protected amphibians and reptiles

The user can create different classifications taking into account the degree of protection.

Similarly, it can be banned to cross certain areas when the user considers that the infrastructure could have a large impact on the habitat and, therefore, on the protected species.

In this case, the user can also insert an image of the specie.

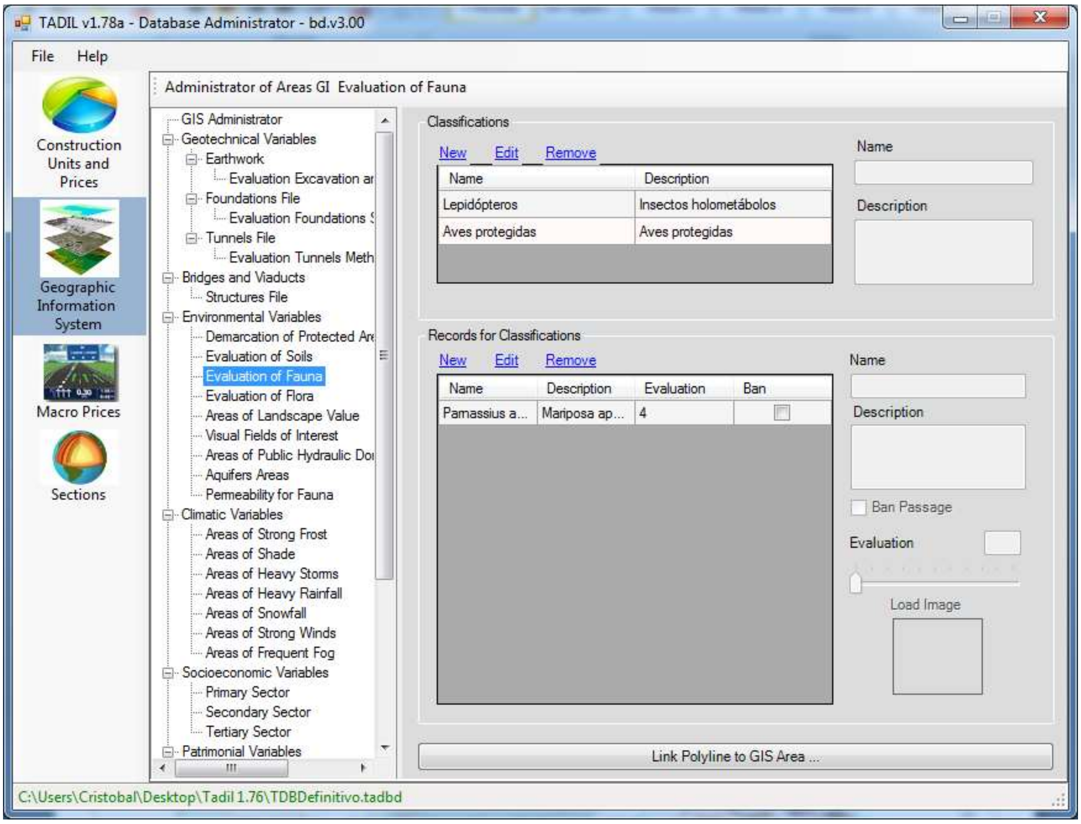


Image 2-26. Software architecture of the input of classifications and areas according to fauna.

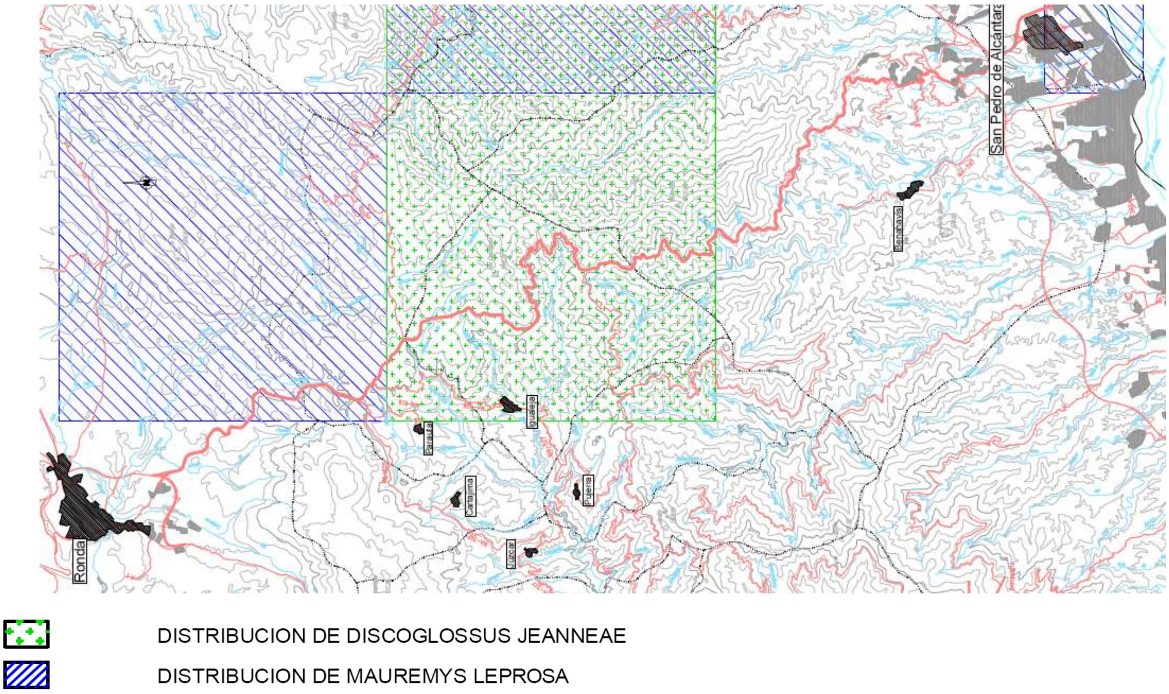


Image 2-27. Example of distribution of protected amphibians and reptiles.

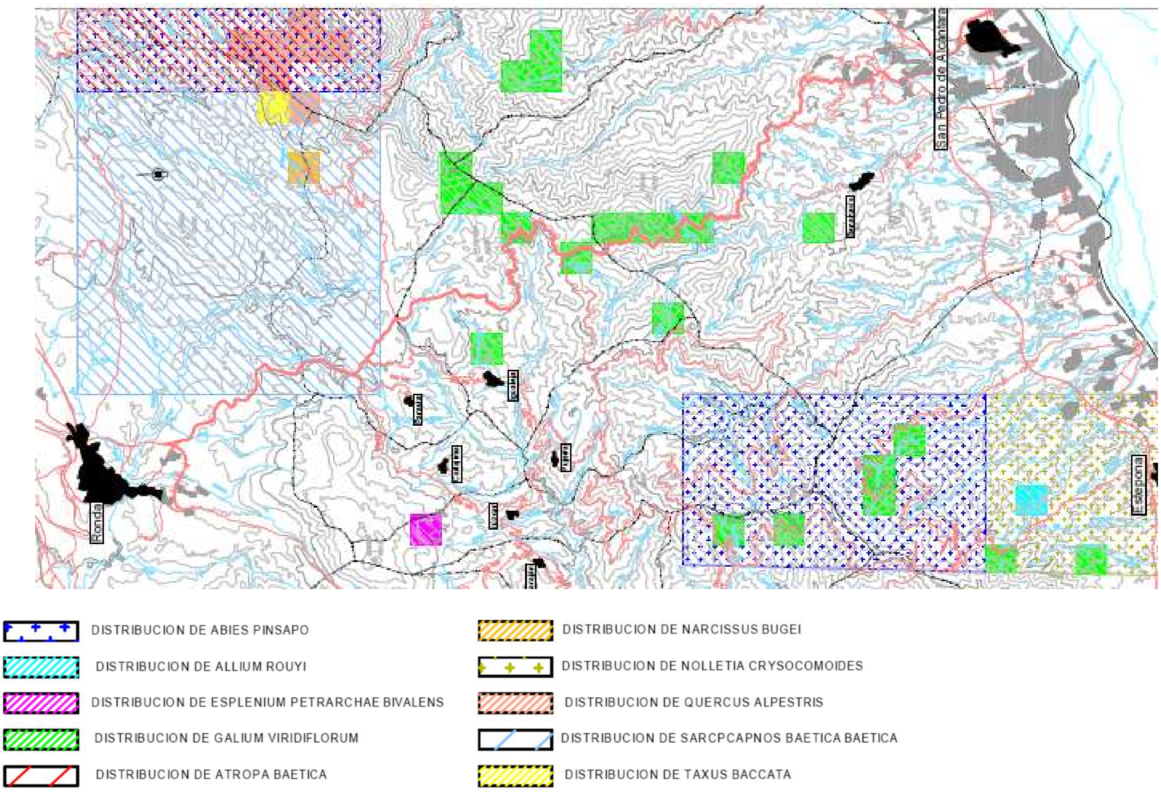


Image 2-28. Example of distribution of protected flora.

1.3. Flora

Similarly, several classifications can be created for these variables. Two of the most common classifications are "protected flora" and "woodland areas". The woodland areas are also divided into different types.

In this case, it can also be banned to cross through certain areas in the alternatives.

Images of the corresponding flora can be inserted into the designated area.

In the square, the user indicates the evaluation of each of the protected species or woodland areas.

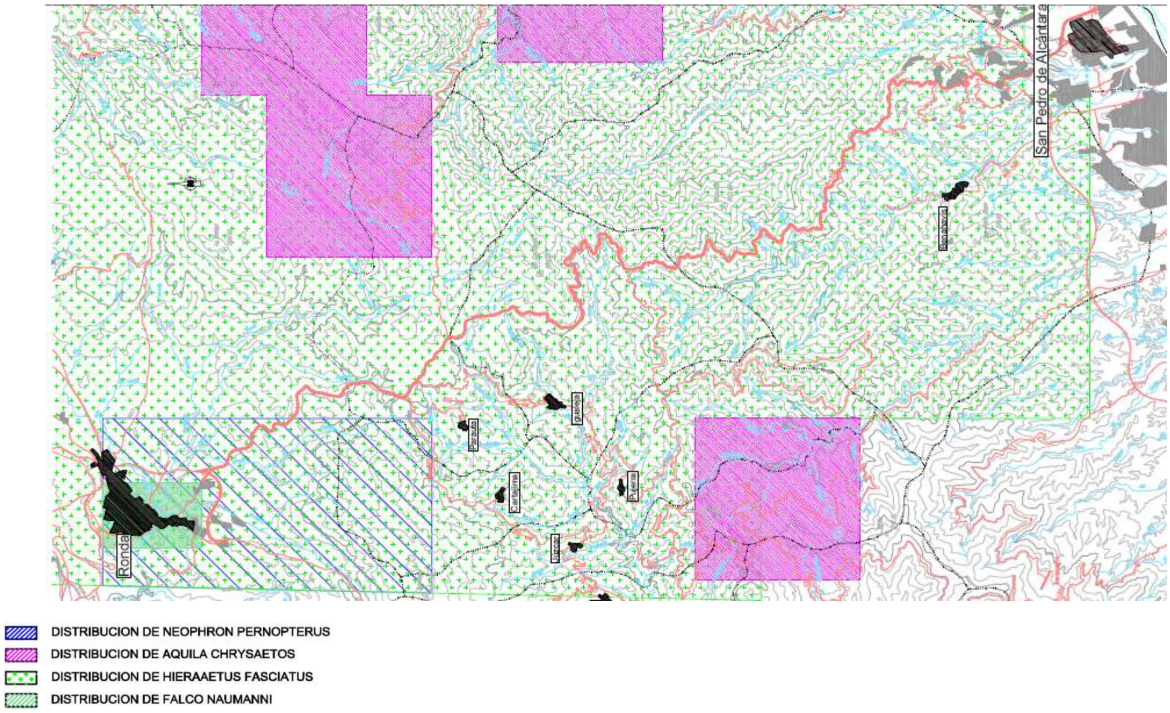
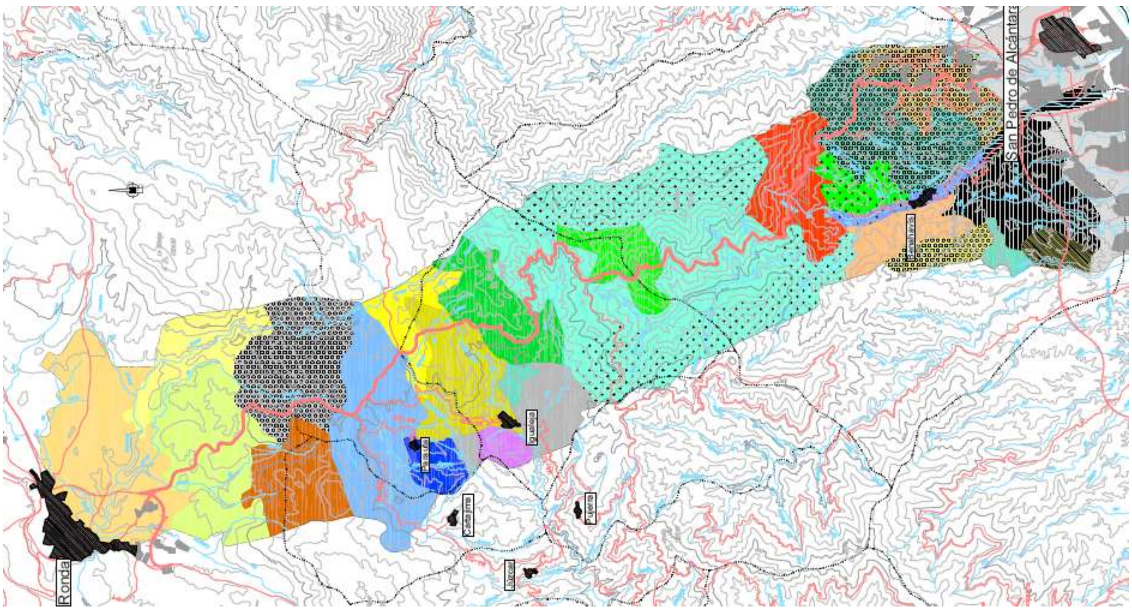


Image 2-29. Example of distribution of protected birds



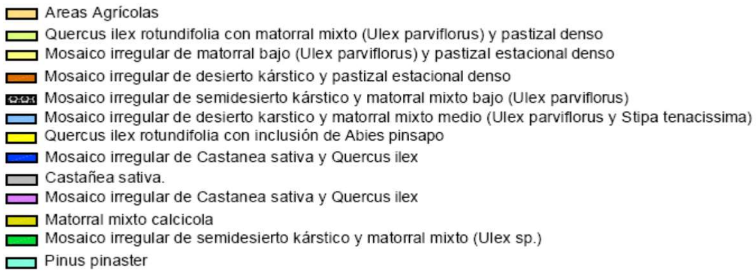


Image 2-30. Example of distribution of woodland areas.

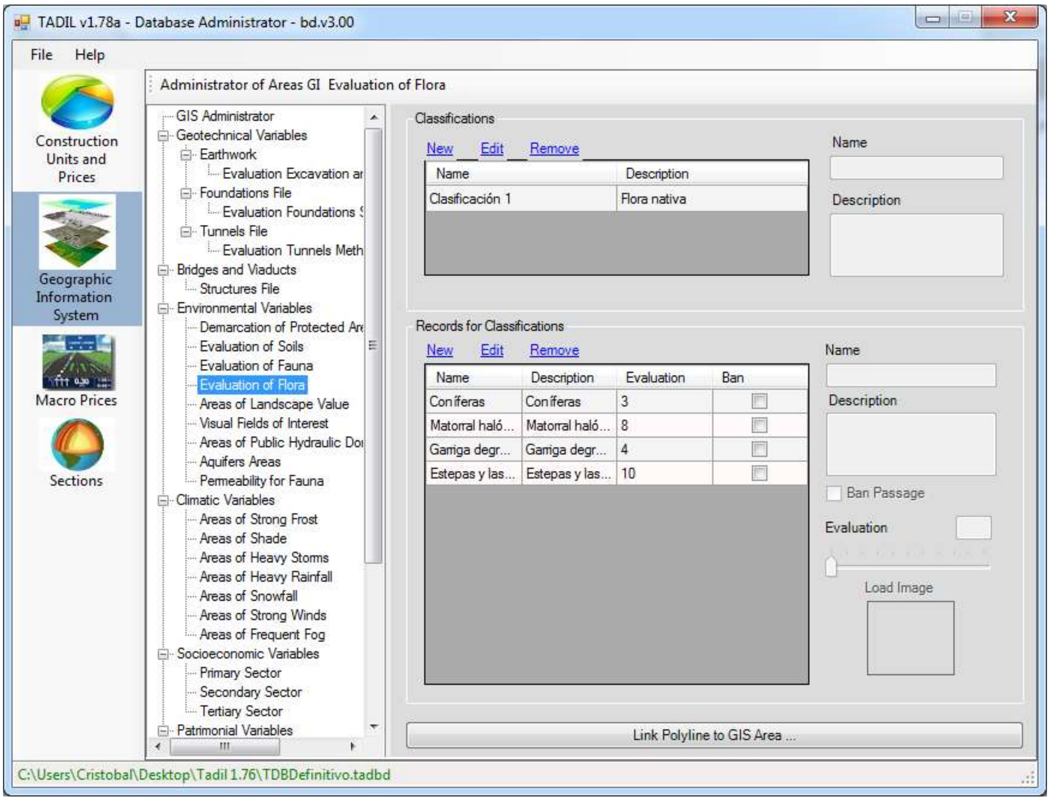


Image 2-31. Design of menu for the input of classifications and areas of flora.

1.4. Soils

The definition of the edaphology of the area of study is the same as above.

The areas can be differentiated by colour.

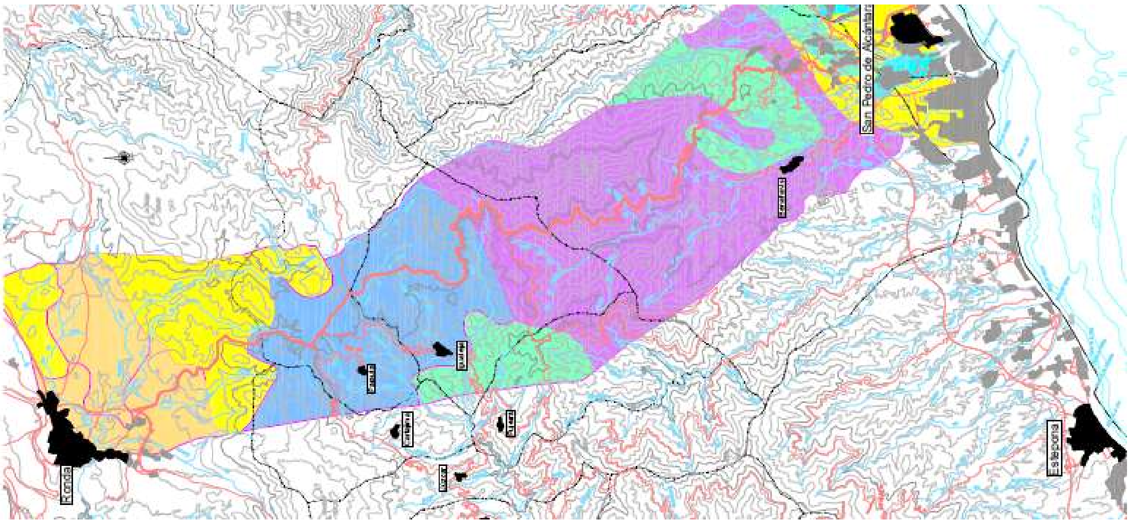


Image 2-32. Example of definition of the edaphology in the area of study.

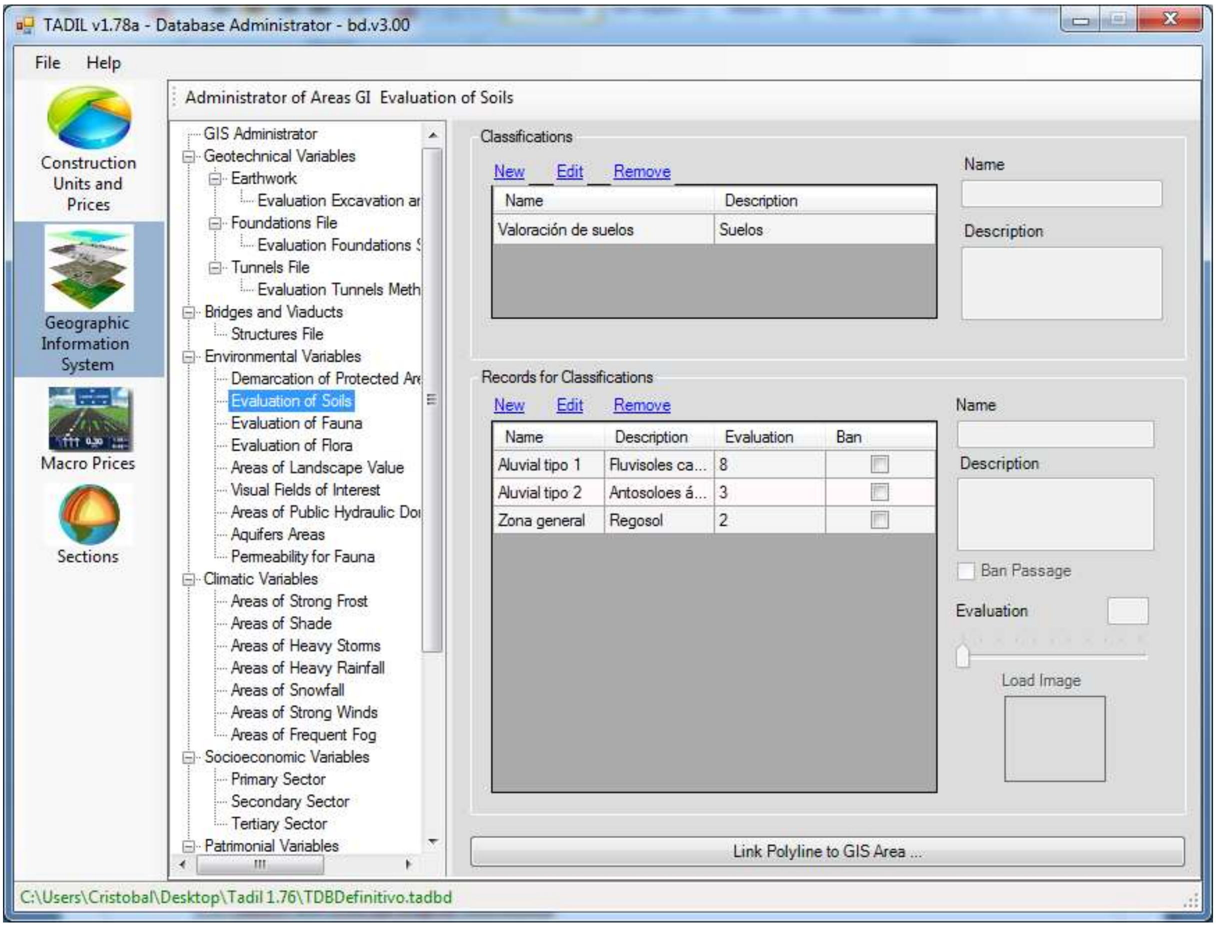


Image 2-33. Menu for the input of soils.

1.5. Hydric and hydrogeological interactions

Regarding hydric and hydrogeological interactions, there is difference between areas of public hydraulic domain and hydrogeological areas.

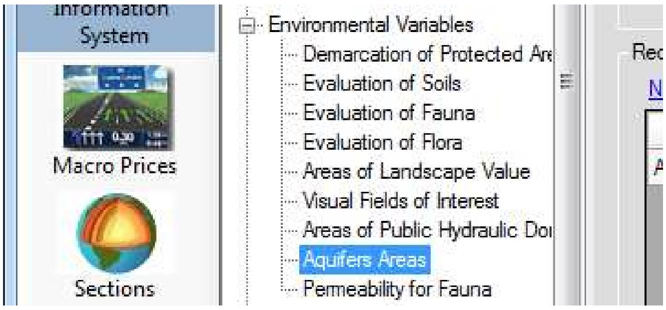


Image 2-34. Selection of hydric or hydrogeological variables.

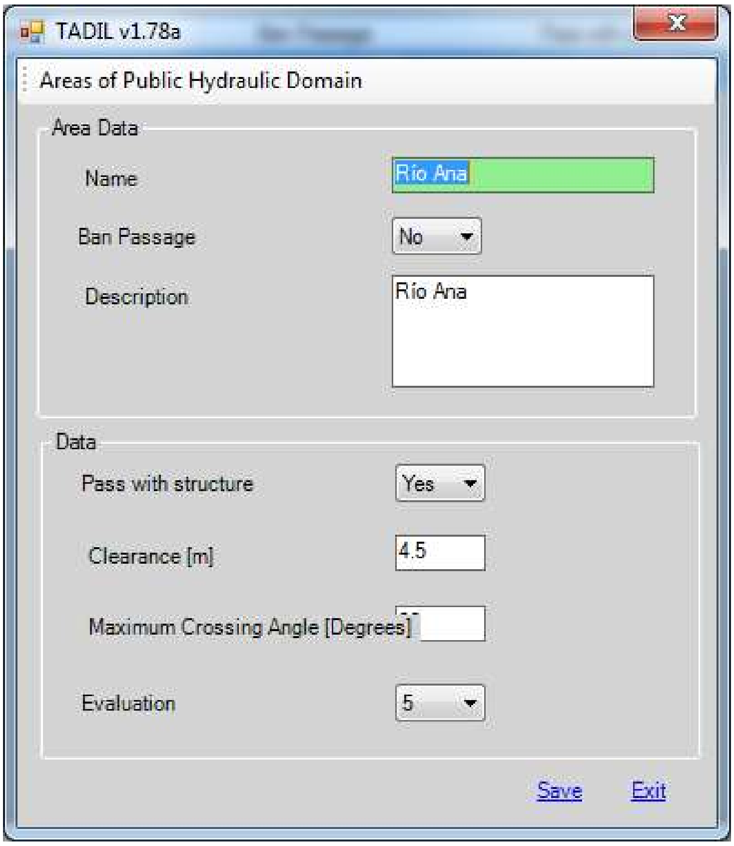


Image 2-35. Software architecture of the Public Hydraulic Domain Menu.

Regarding the areas of Public Hydraulic Domain, the user's evaluation determines a differentiation, so that a stream is not the same as a permanent watercourse. This is the reason why there is a qualitative evaluation.

In this menu, lakes and reservoirs can also be inserted.

When a specific type of structure is to be implemented on the public domain, the Structures file has to coincide with the Public watercourse file.

Aquifers are managed in a similar way as the rest of the environmental parameters, being analysed as a qualitative variable.

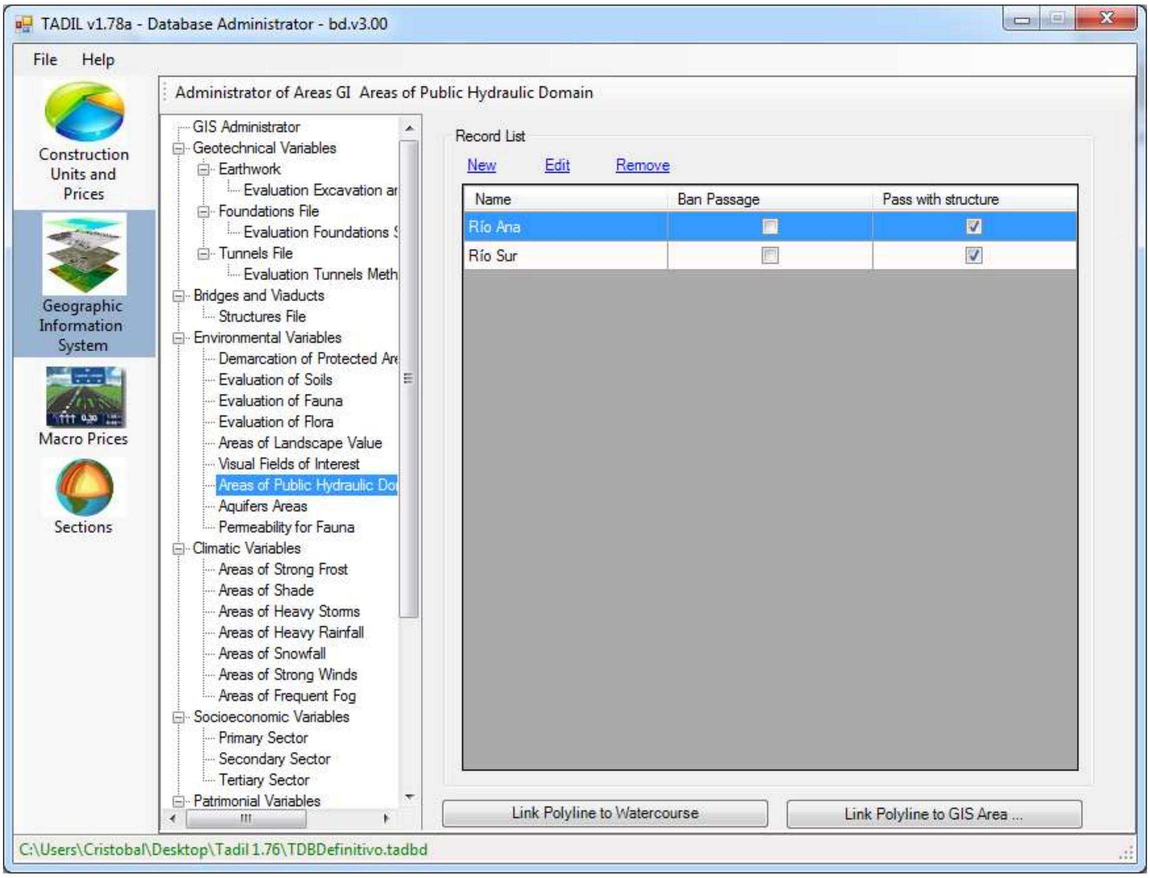


Image 2-36. Input of hydrogeological variables.

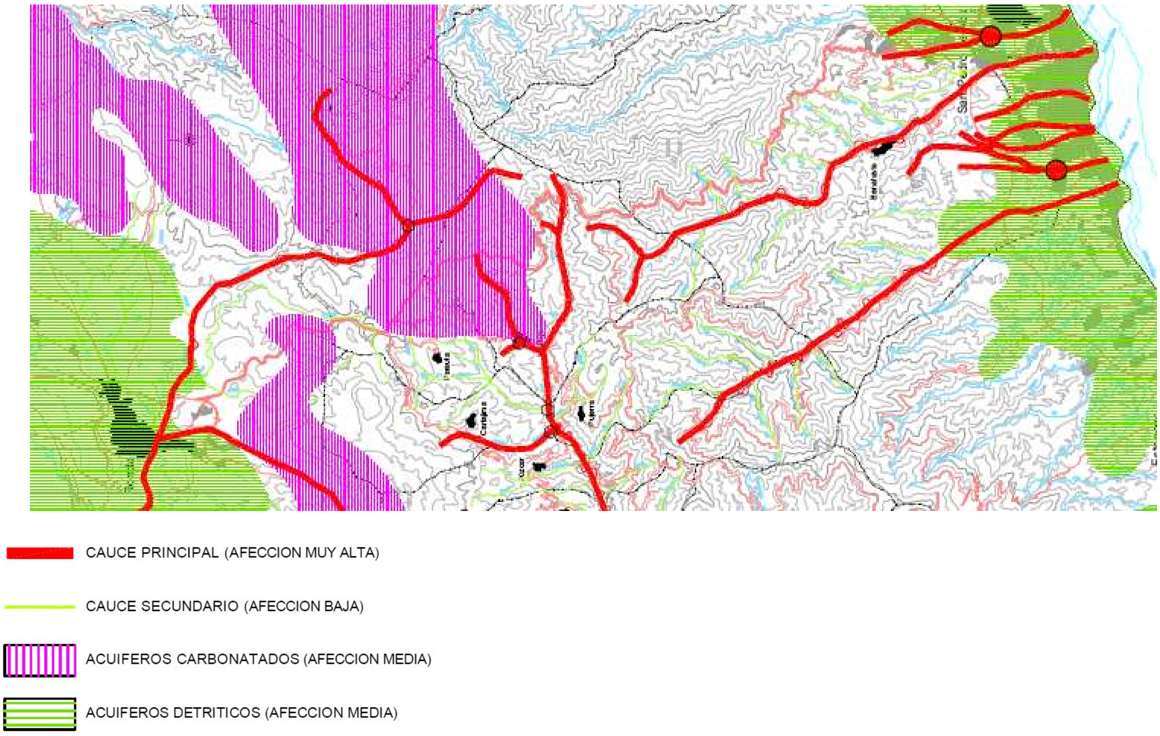


Image 2-37. Input of areas of public domain and watercourses.

1.6. Perceptual environment

The perceptual environment is composed of Areas of Landscape Value (with a qualitative classification) and visual fields that radiate from points of interest, such as viewpoints or populated areas.

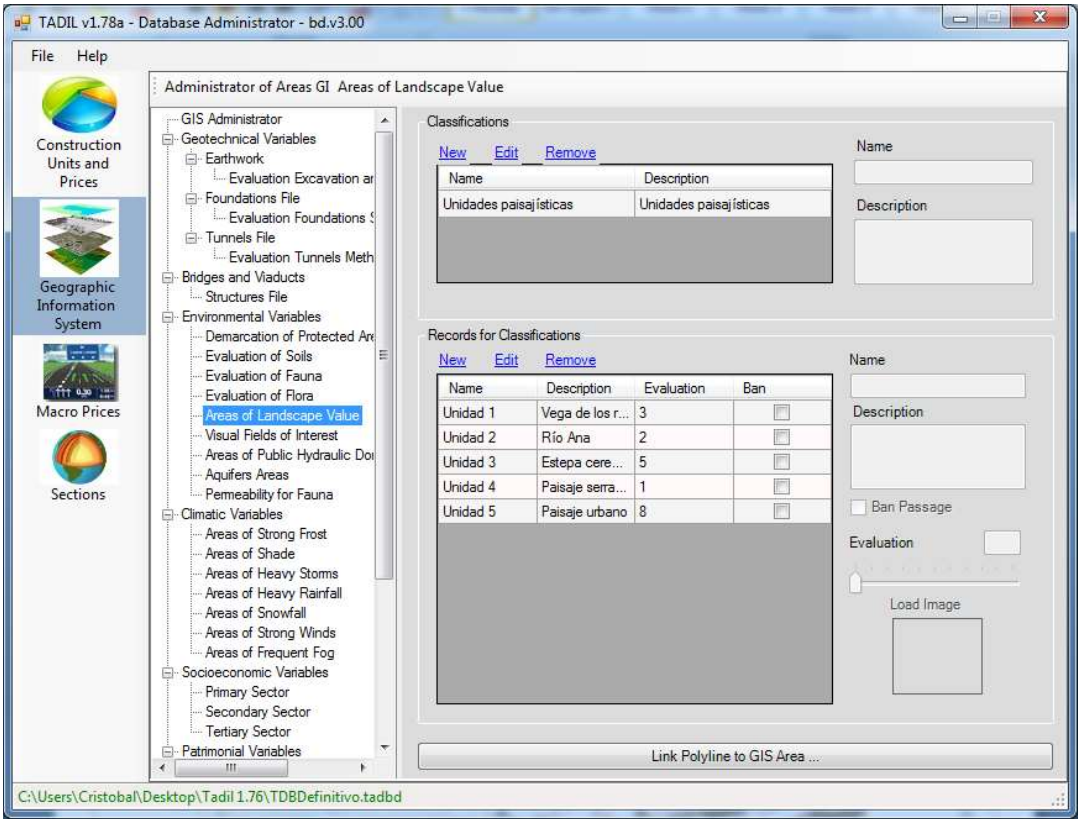


Image 2-38. Areas of Landscape Value.

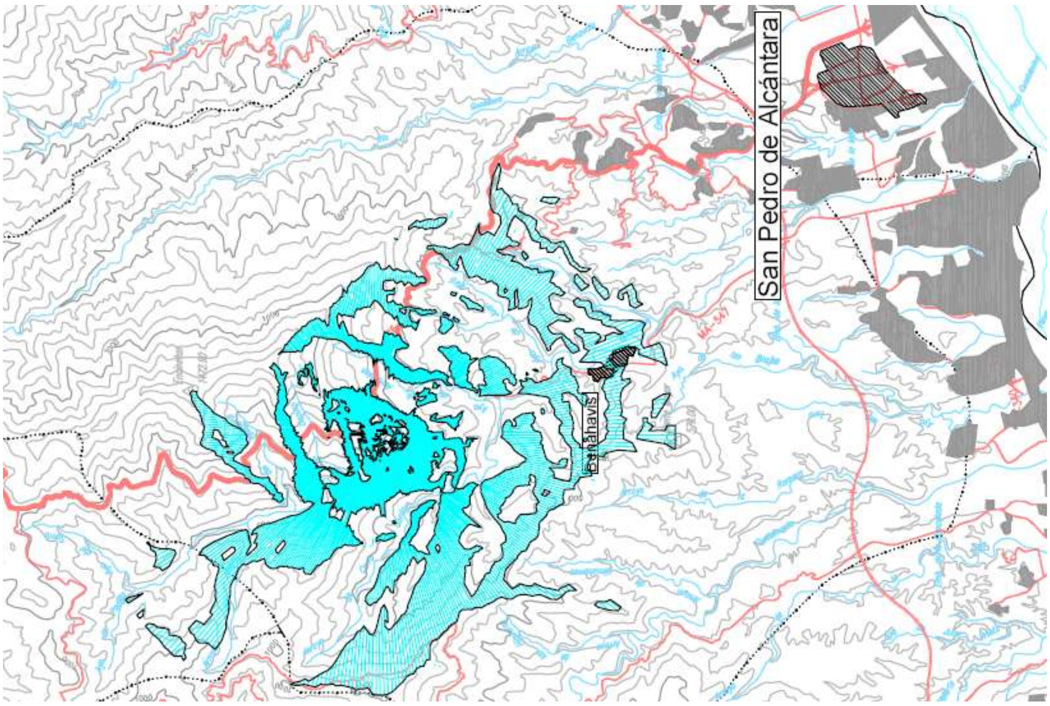


Image 2-39. Example of a visual field obtained from a viewpoint in Benahavis.

Similarly, special landscape interest areas can be defined.

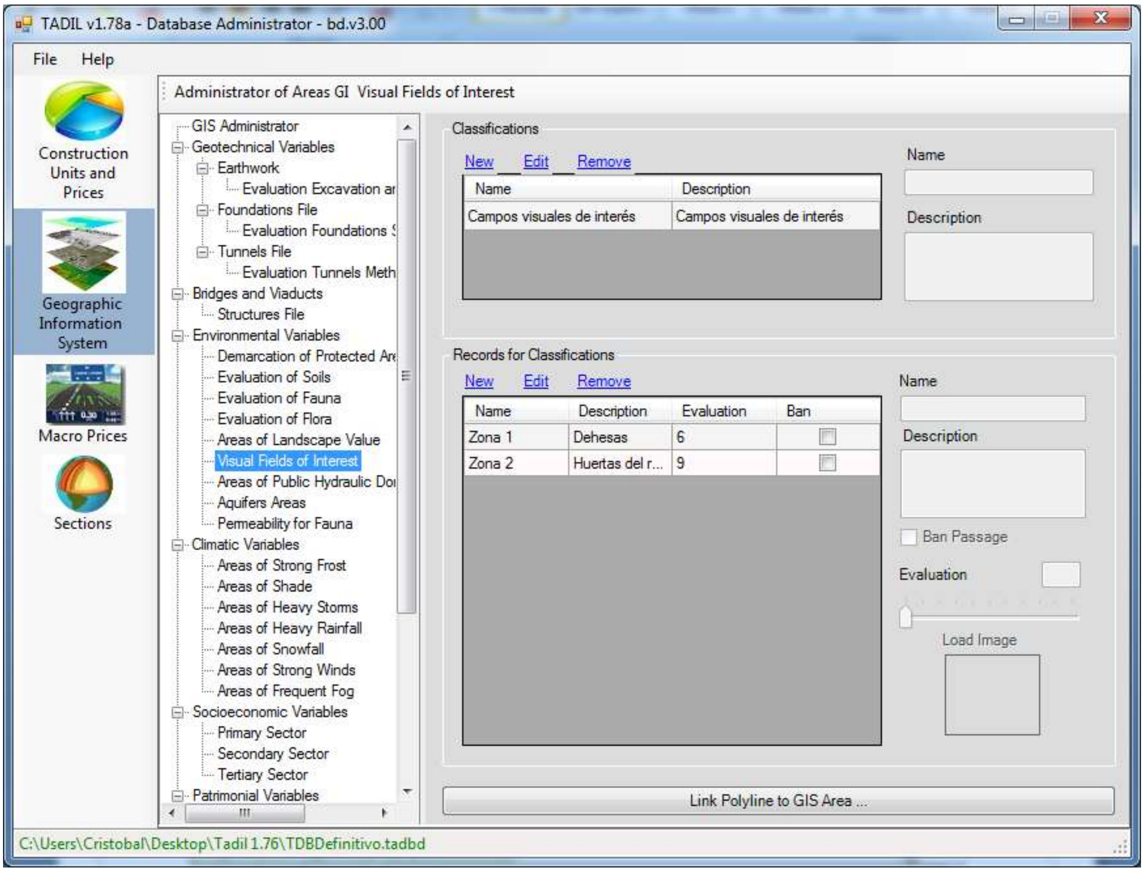


Image 2-40. Menu of the definition of visual fields.

1.7. Permeability for the passage of fauna

In sensitive areas with protected or endangered fauna, the environmental authorities usually demand the placing of wildlife corridors.

Wildlife corridors are placed with the intention of preserving the normal movements of fauna, and avoiding that they cross linear infrastructures. The separation between wildlife corridors depends on the dispersal of the different species and the amount of animals that there are.

The subjective evaluation is worse if there is a large amount of wildlife corridors.

This variable is not equivalent to the evaluation of the variable "Fauna", because in this case the need of **preserving the mobility** of several species inside the territory is evaluated, not the specific species as such. As a result, for example, in an area there may be a large amount of Iberian wild goat, an unprotected species, and it is essential that the daily movement of these animals towards valleys or river beds is guaranteed.

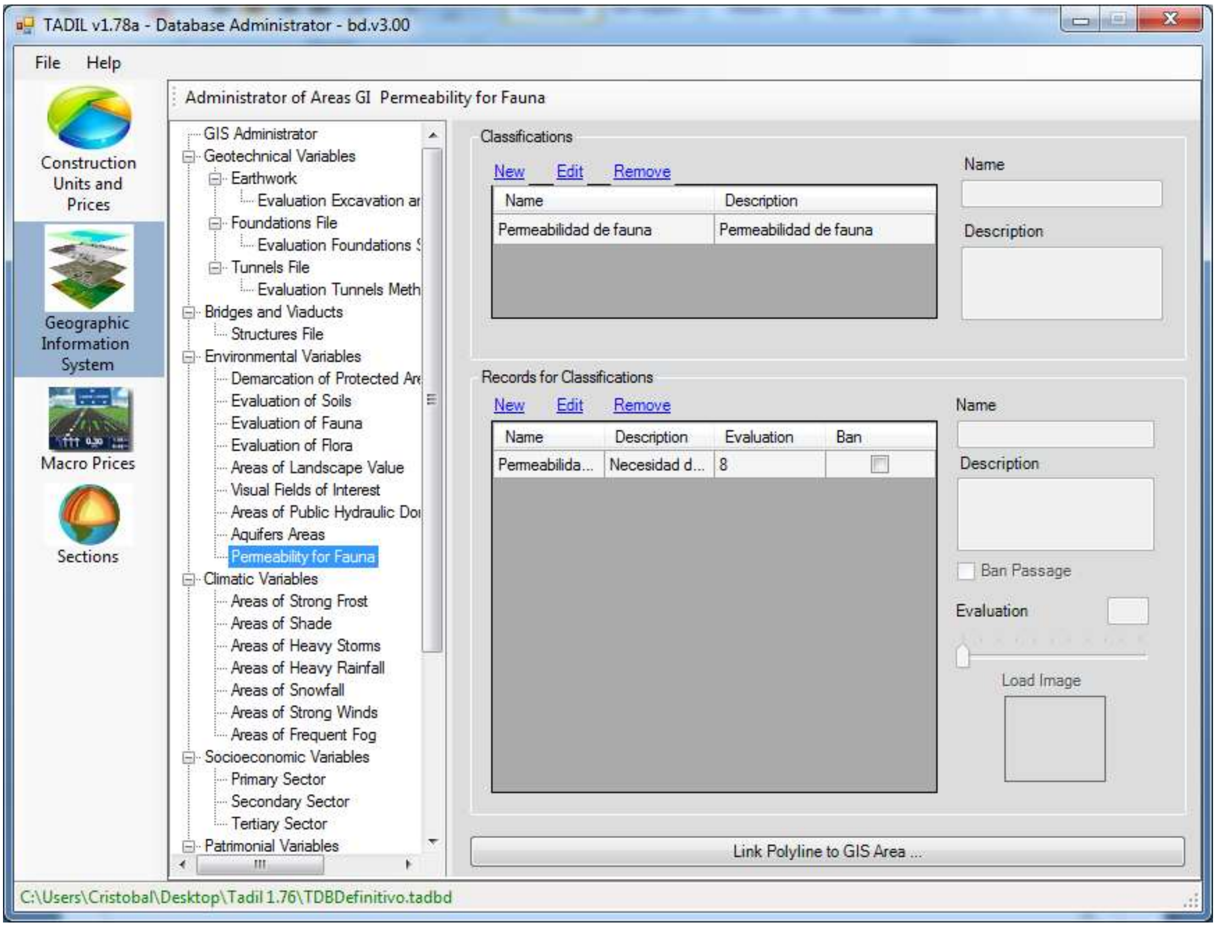


Image 2-41. Menu of evaluation of wildlife corridors.

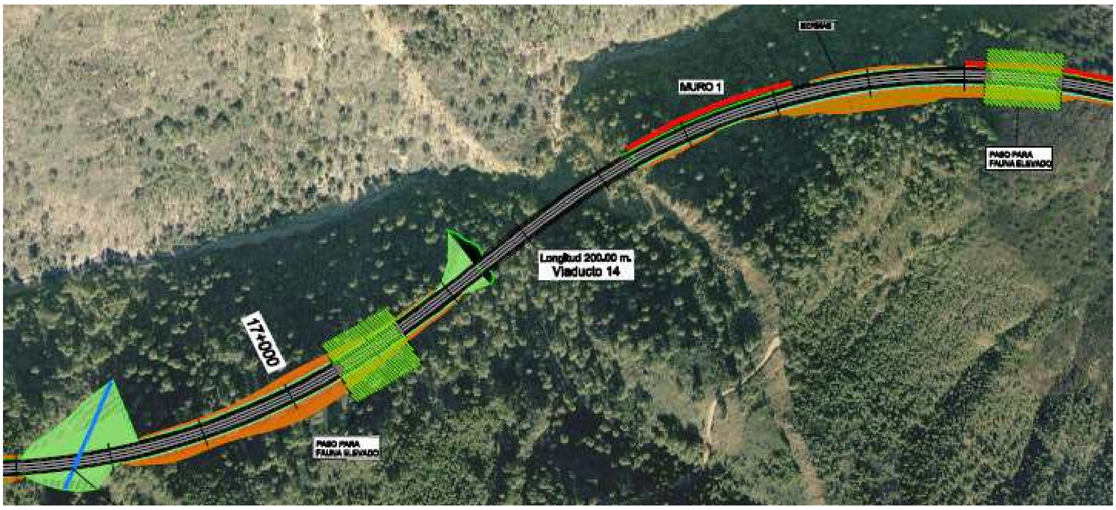


Image 2-42. Example of placement of wildlife corridors in a route.

GEOGRAPHICAL INFORMATION SYSTEM

SUB-CHAPTER 5. CLIMATIC VARIABLES

0. Introduction

In the present chapter, the climatic variables are described, as well as their implementation and their qualitative evaluation.

1. Climatic variables

The climatic variables only have a qualitative character, so they allow a subjective evaluation of the alternatives once they are drafted.

The variables that are implemented are as follows:

- Areas of strong frost
- Shady areas
- Areas of frequent storms
- Areas of heavy rainfall
- Areas of frequent snowfall
- Areas of strong winds
- Areas of frequent fog

All the variables are implemented according to different areas and with a subjective evaluation. The user will be able to create as many classifications as desired. For example, in the variable "Rain": the number of days of rain, average rain per year, etc.

Next, we will describe each of the variables.

1.1. Strong frost

The areas of strong frost correspond to places where it is common for frost to form in cold winter days, and for a layer of superficial ice to prevail the whole day through, or most of the day. It is recommended that the routes do not cross through these areas, due to their accidentality.

In general, this variable is standardised according to **the number of days with minimum temperatures below 3°C**. The higher the number of days with this characteristic, the lower the evaluation.

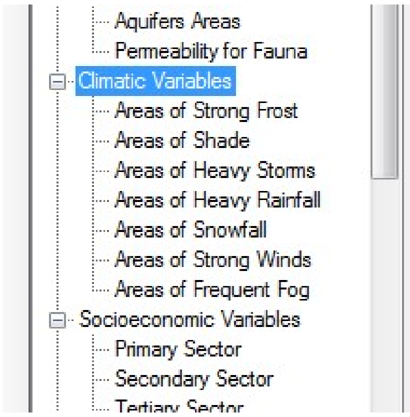


Image 2-43. Selection of climatic variables.

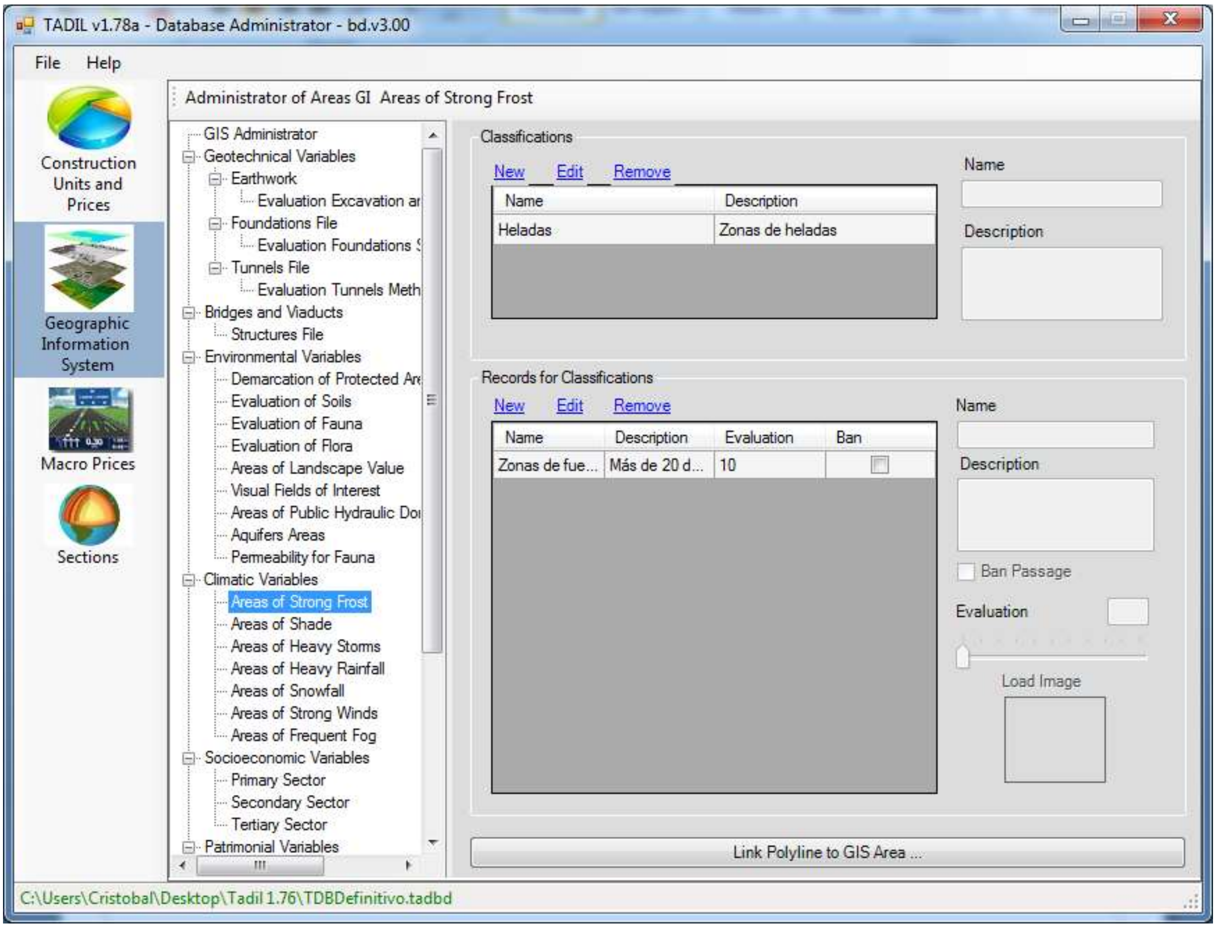


Image 2-44. Software architecture of the Areas of Strong Frost Menu.

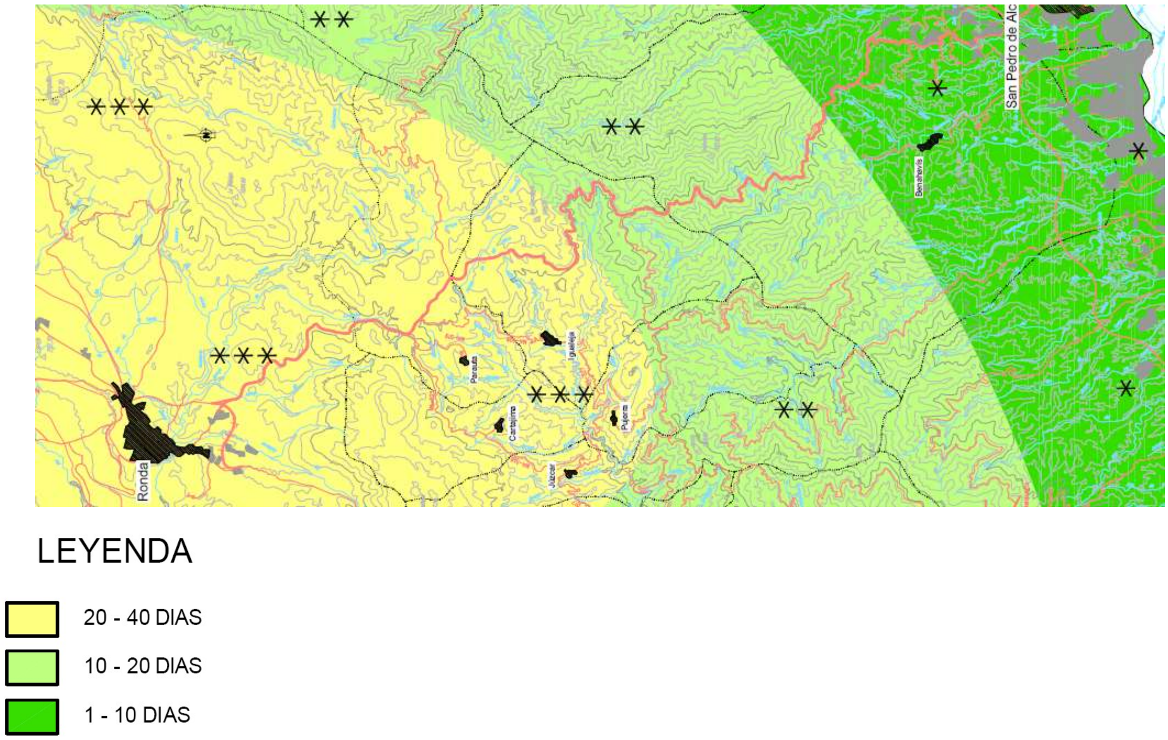


Image 2-45. Example of delimitation of areas according to the number of days of frost.

1.2. Shady areas

The areas in the shade are related to the formation of frost in the mornings and evenings, due to the short amount of hours of sunlight during the day. This contributes to the formation of localized sheets of ice. On these slopes, the temperature can be 10°C lower than in areas with a better solar orientation (sunny areas), allowing more endurance of the snow or ice.

In the northern hemisphere, this effect is especially harsh on the northern slopes of mountain ranges with an **East-West orientation**. In the southern hemisphere, on the contrary, this takes place on the southern slopes of mountain ranges with the same orientation (an East-West orientation).

There are numerous roads with accident blackspots linked to this characteristic.

In general, there is usually only one evaluation for shady areas, unless the user wishes to establish differences between certain areas.

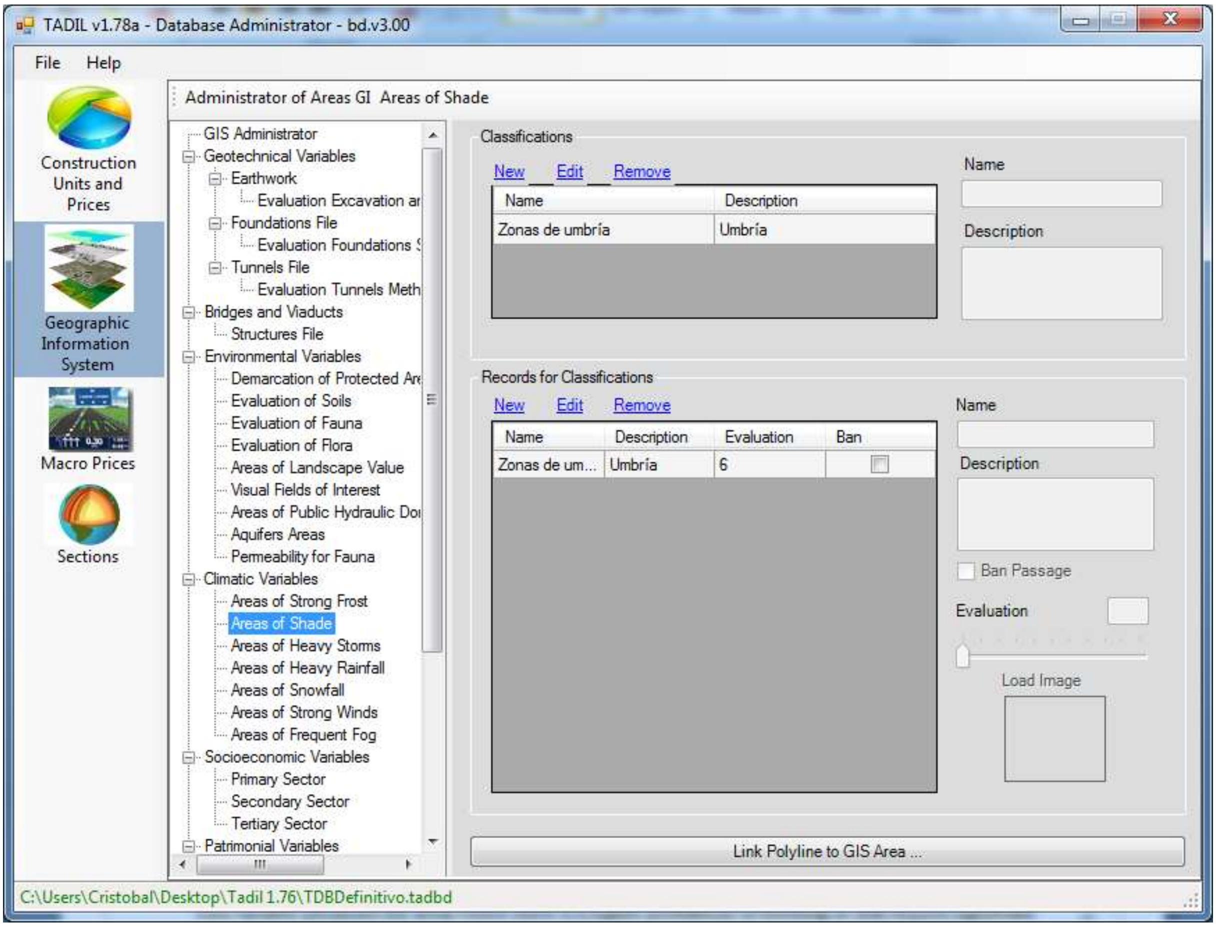


Image 2-46. Software architecture of the Shady Areas Menu.

1.3. Areas of frequent storms

In this case, the effect of rainfall on the orography of the terrain is taken into account. This variable considers geographical areas with frequent **torrential rain** and topographies in which **river beds and streams** present important **longitudinal slopes** and highly concentrated **ramified structures.**

This variable penalizes the areas where there is a higher probability of flooding or that require significant reparations of the longitudinal and transversal drainage systems, with their corresponding costs.

Considering a specific field of study and the digital model of the terrain, the areas where the watercourses may overflow should be located, or the areas where there may be a concentration of streams or streamlets.

These areas don't necessarily have to coincide with the areas of public hydraulic domain that demarcate the flooding area for a specific return period and a specific watercourse. In this case, the areas where the infrastructure will probably flood are demarcated. The flooding is due to a failure of the longitudinal and transversal drainage systems motivated by torrential watercourses, generally of little importance, that don't usually have a public hydraulic domain area assigned to them.

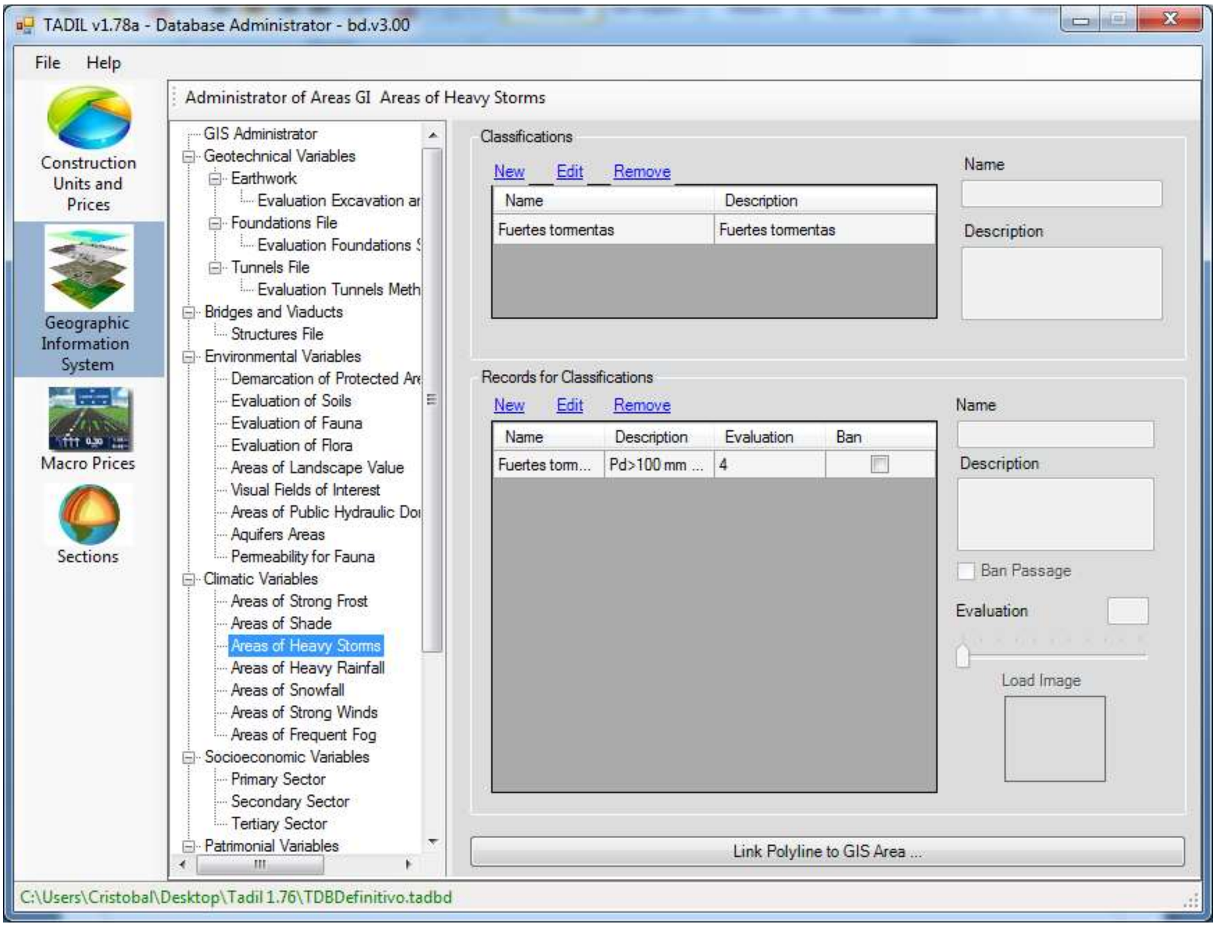


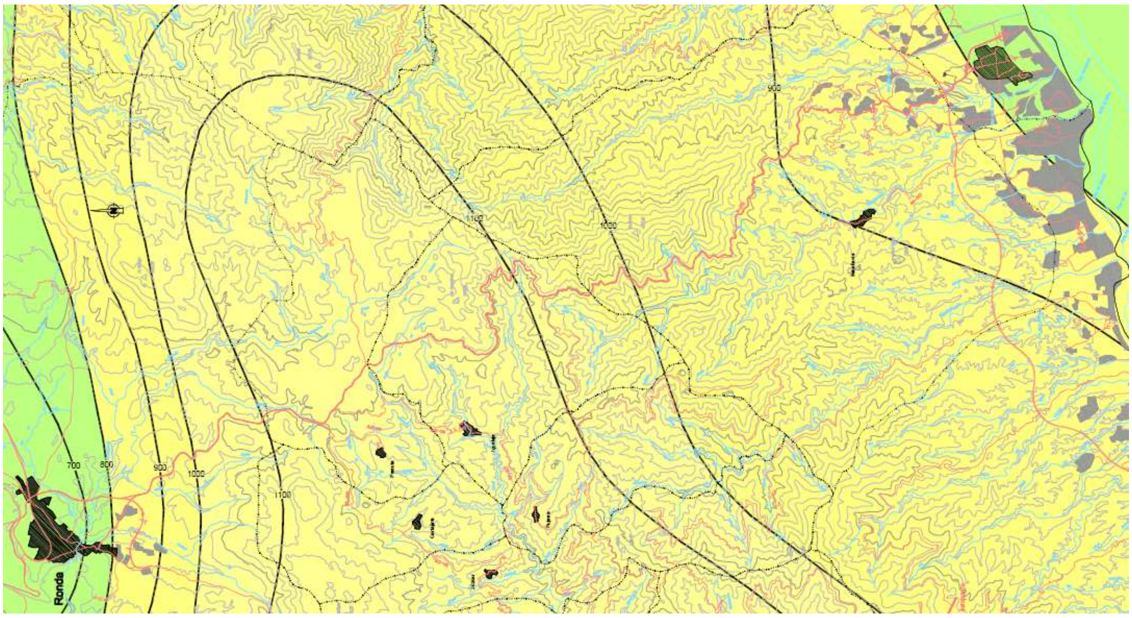
Image 2-47. Software architecture of the Areas of Frequent Storms Menu.

1.4. Areas of heavy rainfall

This variable penalizes the areas where there is a high frequency of rainfall. The effect of a larger amount of rainfall per year on an infrastructure requires:

- a higher protection of the slope and/or less verticality of the slope
- more conservation
- more drainage beneath the esplanade
- more scalings

Generally, local differences can be observed in the pluviometry of high mountain areas and areas of lower heights. Thus, **the evaluation is usually carried out in accordance with the value of the average yearly rainfall**. Another option is performing the evaluation regarding the number of rainy days per year.



Precipitacion Media en M/M   Clasificacion

> 800…………………………………HUMEDO

600 - 800……………...............SUBHUMEDO

Image 2-48. Example of demarcation of areas according to yearly rainfall.

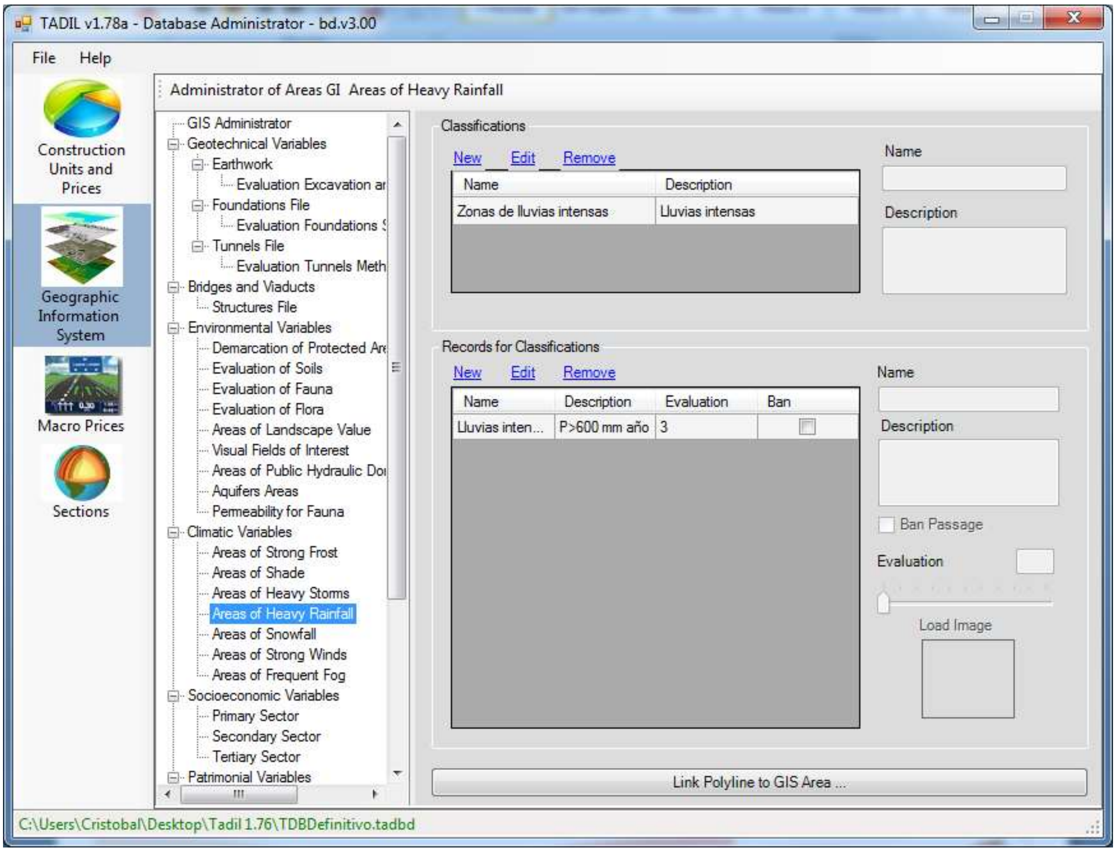


Image 2-49. Software architecture of the Areas of Heavy Rainfall Menu.

1.5. Areas of frequent snowfall

This variable penalizes the areas where there is a high frequency of snowfall, which may accumulate on the esplanade and, consequently, make the infrastructure ineffective.

The evaluation of the variable is carried out taking into account **the number of days per year of registered snowfall**.

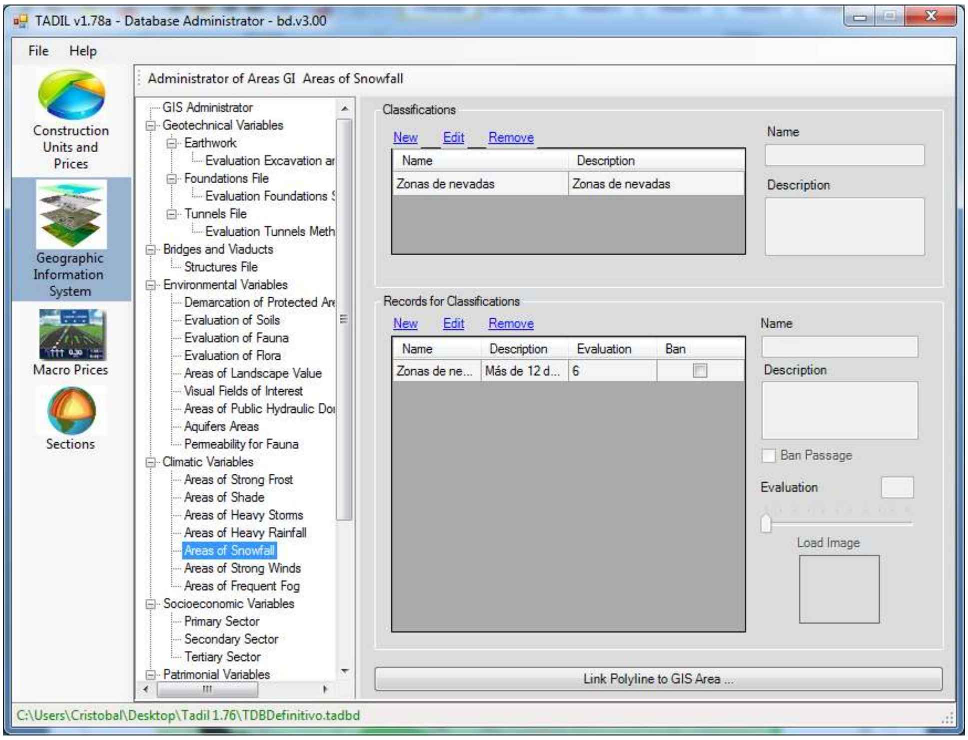


Image 2-50. Software architecture of the Areas of Frequent Snowfall Menu.

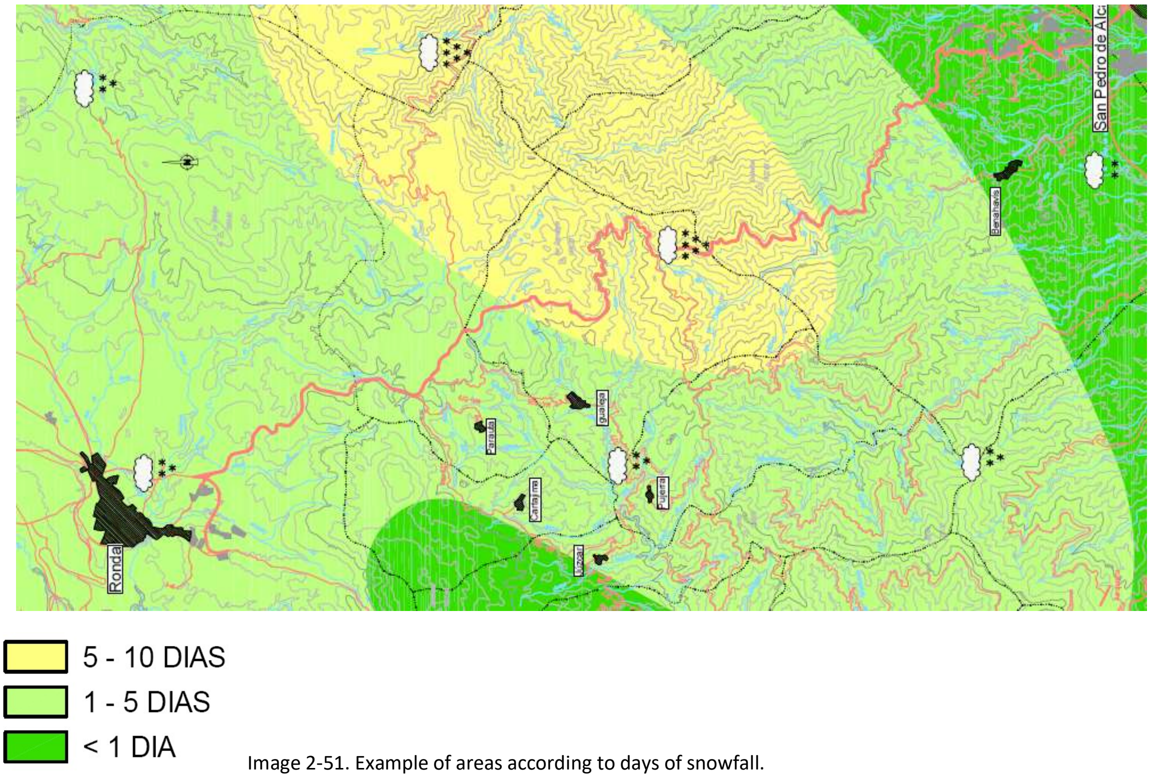


Image 2-51. Example of areas according to days of snowfall.

1.6. Areas of strong winds

This variable corresponds to areas in which the frequency of strong winds constitutes a risk factor when driving. Therefore, the evaluation of this variable is directed towards road infrastructure. It usually corresponds to the **peaks of mountain ranges with a higher geographical prominence,** as well as specific **areas in the coast**.

In general, there is usually only one evaluation for areas with strong winds, unless the user wishes to establish differences between certain geographical areas with different climatic features.

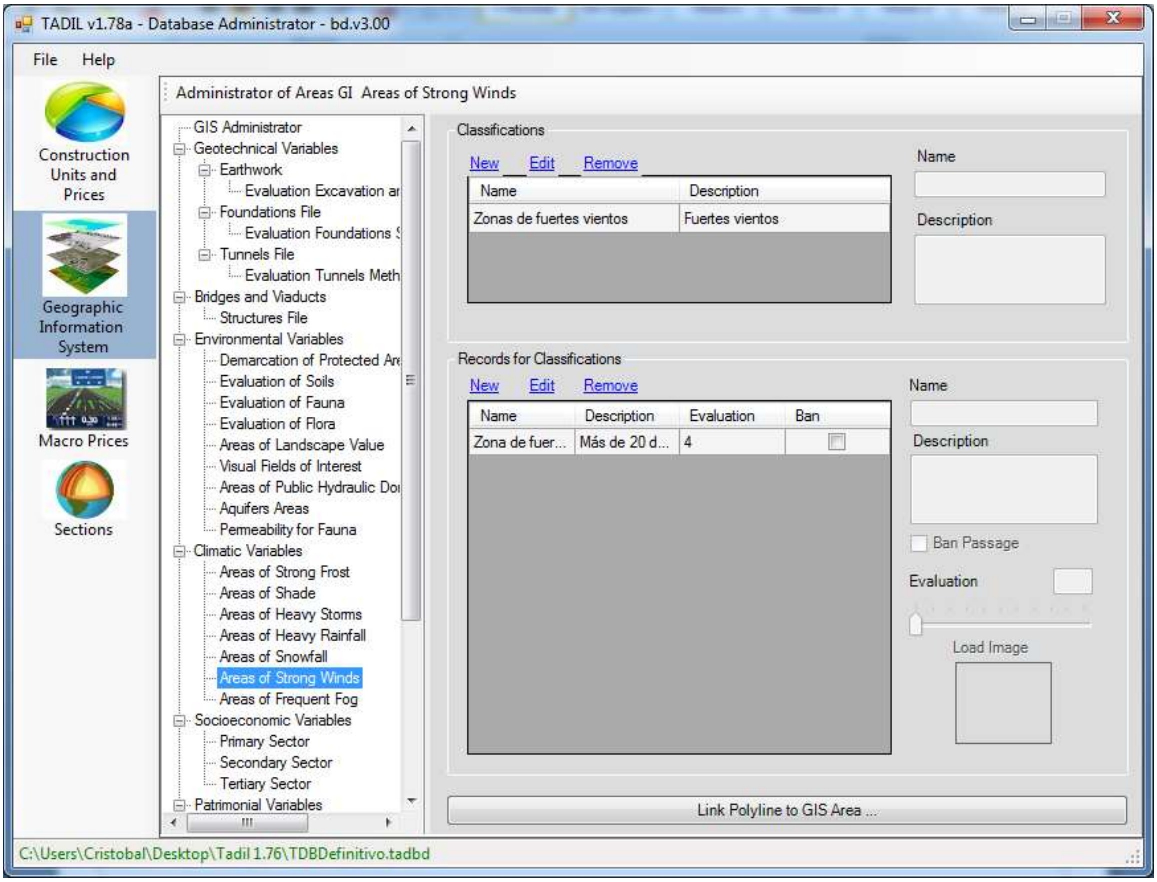


Image 2-52. Software architecture of the Areas of Strong Winds Menu.

1.7. Areas of frequent fog

This variable corresponds to places where fog is frequent. The valley fog or slope fog form because of the concentration of cold air that gets confined on the foothills of mountain ranges. The radiation fog or advection fog, on the other hand, coincide with the areas in which the cooling of the ground during the night produces the concentration of humidity in the lower part of the atmosphere. They usually take place in plains and high plateaus.

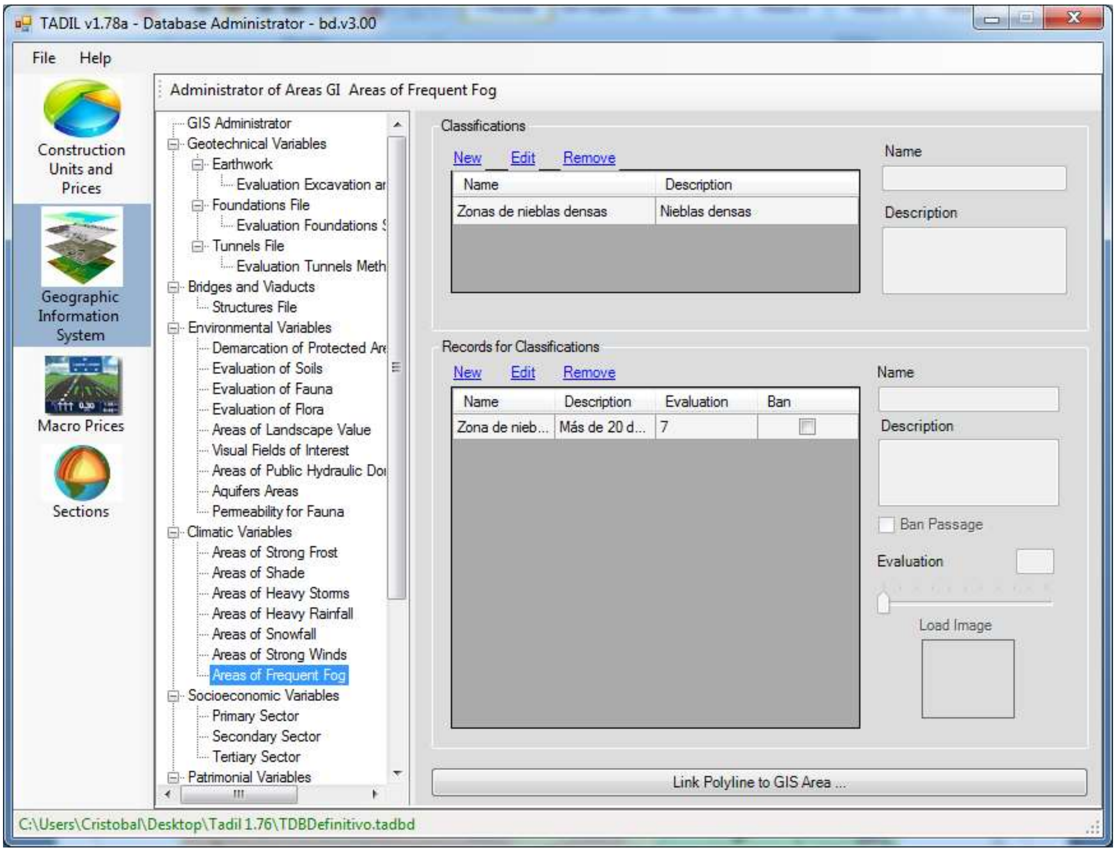


Image 2-53. Software architecture of Areas with Frequent Fog Menu.

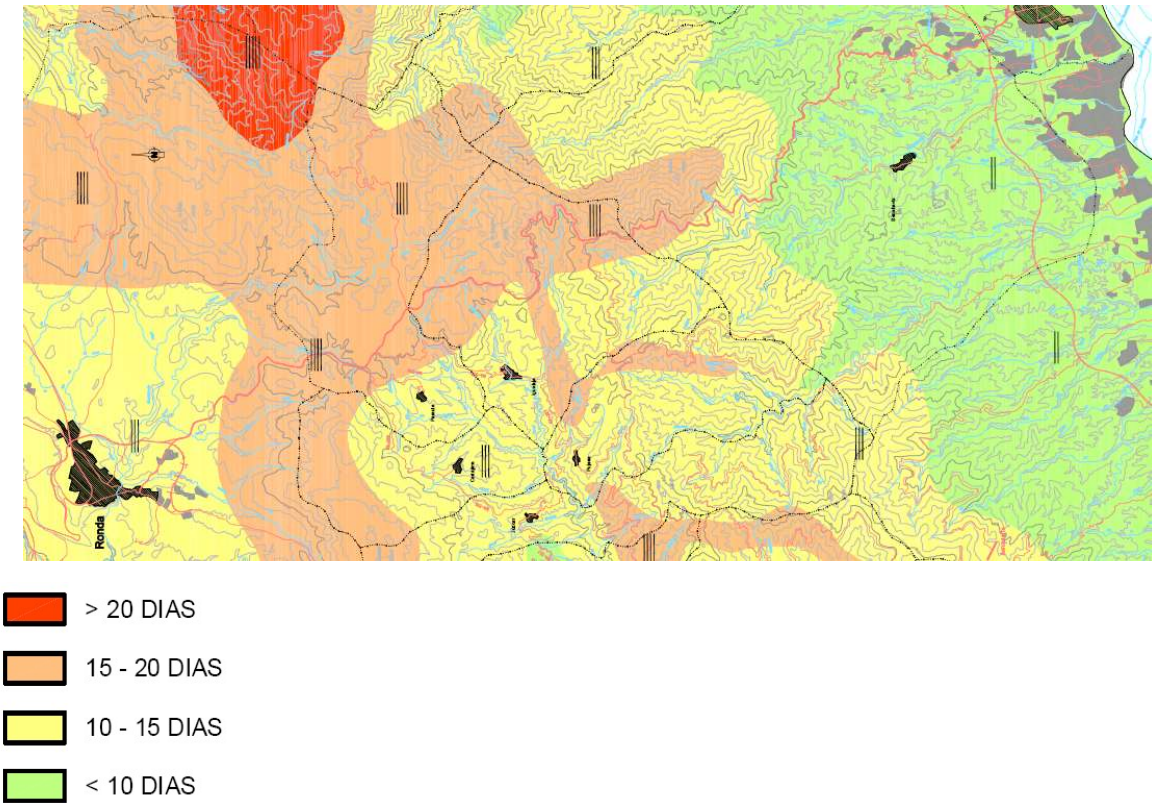


Image 2-54. Example of zoning according to days of fog.

GEOGRAPHICAL INFORMATION SYSTEM

SUB-CHAPTER 6. SOCIO-ECONOMIC VARIABLES

0. Introduction

In the present chapter, the socio-economic variables are described, as well as their implementation and their qualitative evaluation.

1. Socio-economic variables

The socio-economic variables try to analize the value of the land based on its productivity. A top priority is the non-impact of the implementation of infrastructures in areas with high productivity which are related to relevant socio-economic parameters, such as employment.

Therefore, the user must emphasize the relevant areas with productivity in the Primary, Secondary and Tertiary sectors.

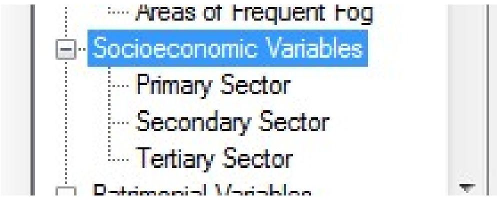


Image 2-55. Selection of sectors.

The economic sectors allow classifying the economic activities of a territory, taking into consideration the type of productive process that is developed. It is subdivided into Primary, Seconday and Tertiary sectors, and recently, also Quaternary sector. However, this last sector will not be taken into account here, since it refers to highly intellectual activities such as research, development, innovation and information, which are very far from localizing aspects. They will be integrated into the Tertiary sector.

1.1. Primary sector

This sector obtains products directly from nature, such as raw materials.

- **Agriculture** (of vegetable origin)
- **Animal husbandry** (of animal origin)
- **Fishing** (in a river or sea)
- **Mining** (in mines and other rocky complexes)
- **Silviculture** (of forests)

The user will be able to create areas with different evaluations. In this way, an unirrigated land is not the same as an irrigated land or a greenhouse plot. Similarly, a plot of pasture land is not the same as a plot of land for planting poplars.

The Land Register databases can be used and implemented into the program.

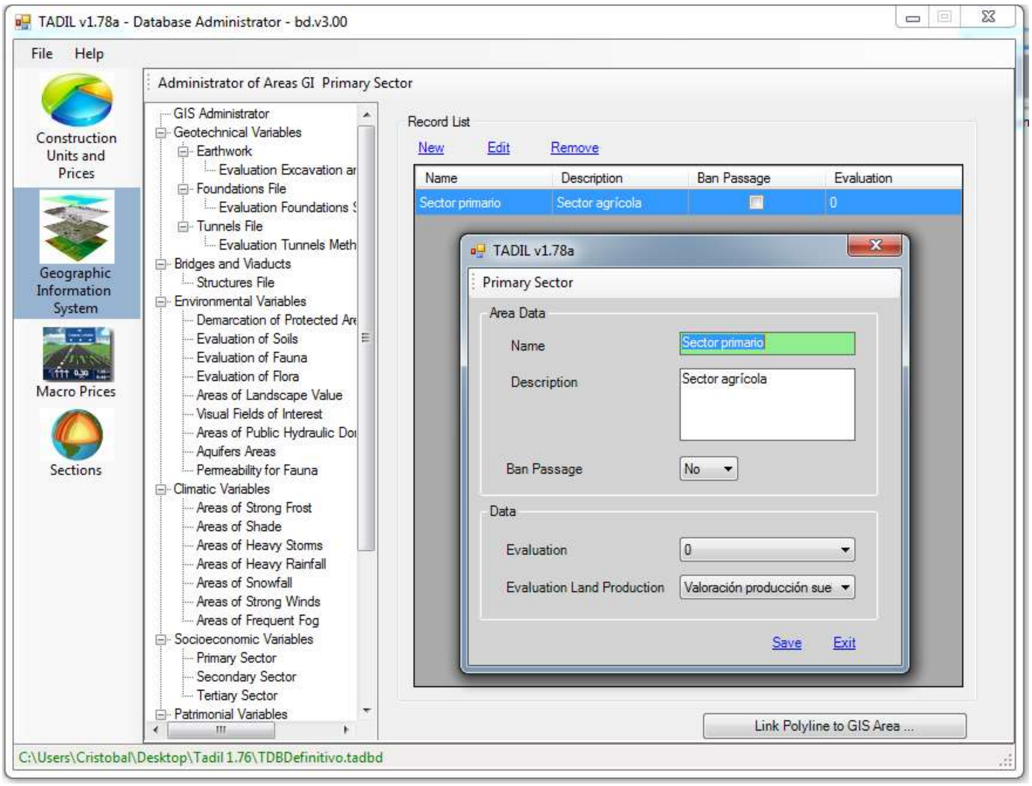


Image 2-56. Software architecture of the Primary Sector Areas Menu.

In the abovementioned menu, the code allows connecting the prices in the database to expropriation costs regarding productivity. The cost of the expropriation will be taken into account in the patrimonial variables.

1.2. Secondary sector

This sector transforms raw materials into finished or semi-manufactured products:

- Industry
- Energy
- Mining (also considerd part of the secondary sector because some products can be produced from mining)
- Construction

In general, industrial sectors in production are usually avoided in the drafting of linear infrastructures. The user must indicate the banned areas. However, in some situations, the total or partial expropriation of a secondary complex can be interesting in order to optimize the infrastructure. In this case, the user must indicate with a code the cost of the expropriation in relation to productivity.

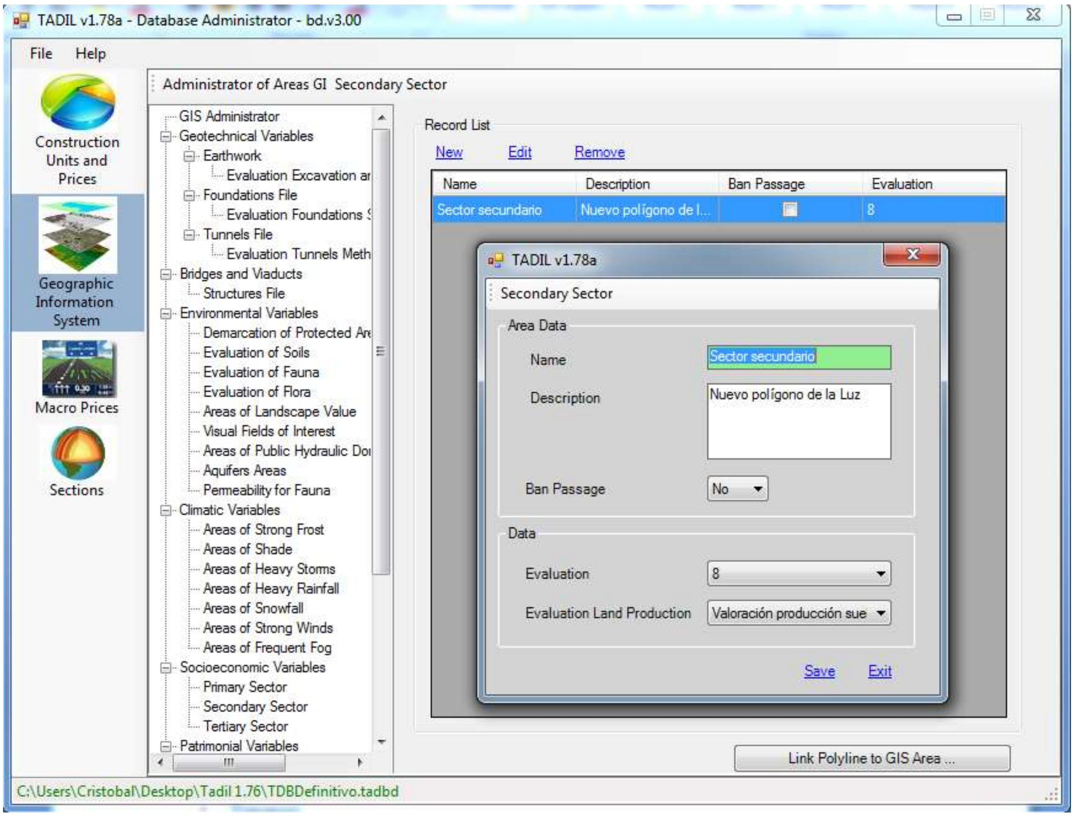


Image 2-57. Software architecture of the Secondary Sector Areas Menu.

1.3. Tertiary sector

This sector is also known as the service sector, because it does not produce goods, only services.

- Transport
- Communication
- Trade
- Tourism
- Health care
- Education
- Finance
- Administration

In this case, the user designates areas such as science parks, educational complexes, university areas, large health care complexes, etc.

Similarly, the user can indicate banned areas or the cost of the expropriation in relation to productivity.

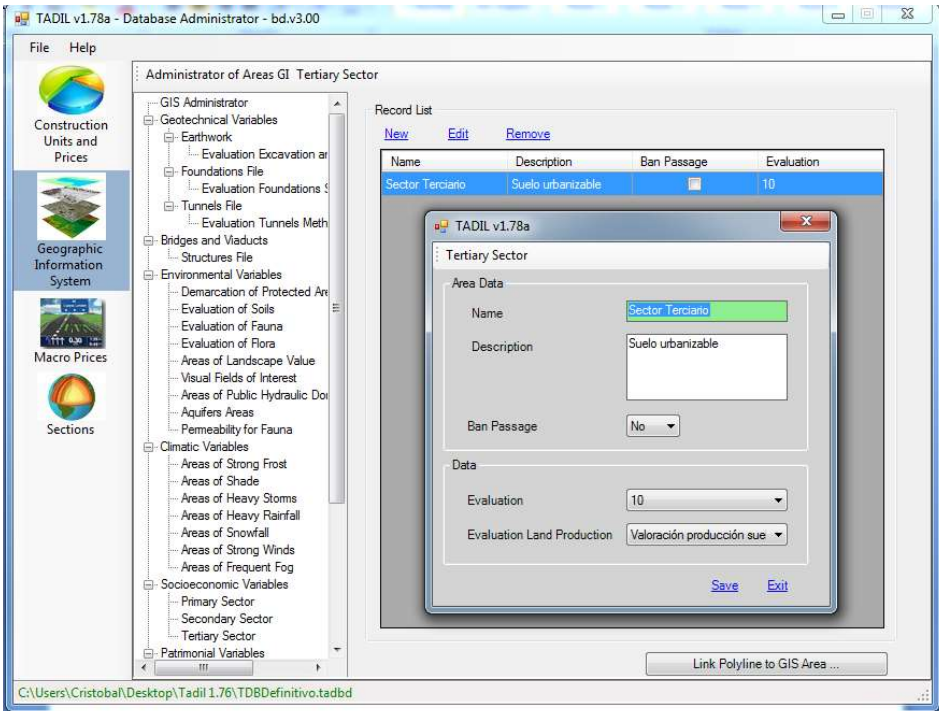


Image 2-58. Demarcation of areas of the Tertiary sector.

SUB-CHAPTER 7. PATRIMONIAL VARIABLES

0. Introduction

In this chapter, the set of patrimonial variables is described. There is a total of nine qualitative-type variables.

1. Patrimonial variables

This group includes patrimonial elements, both private and public property subject to contributions or properties of mandatory conservation because of their strategic or cultural interest. The former can have an economical value assigned to them. For the latter, the evaluation specified by the user allows giving priority to the elements of higher value, or anticipating the creation of banned areas.

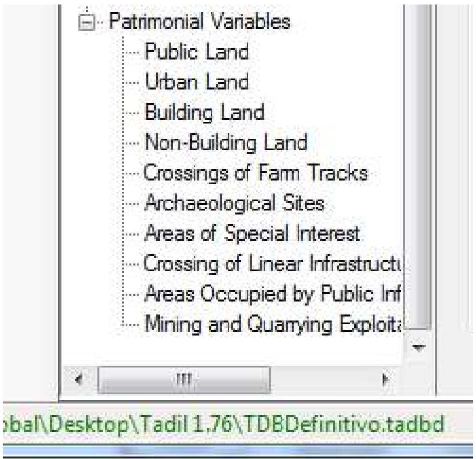


Image 2-59. Software architecture of the selection of patrimonial variables.

1.1. Public Land

This includes the land that is public or belongs to a municipality. The protection of these lands corresponds to the criteria of municipal or regional planning (ordinances and specific plannings). The lower the evaluation of these areas, the higher the protection is. The user will also be able to indicate the banned areas.

In this case, the evaluation responds exclusively to patrimonial criteria, because other criteria such as environmental conditions will already have been taken into account in the environmental variables.

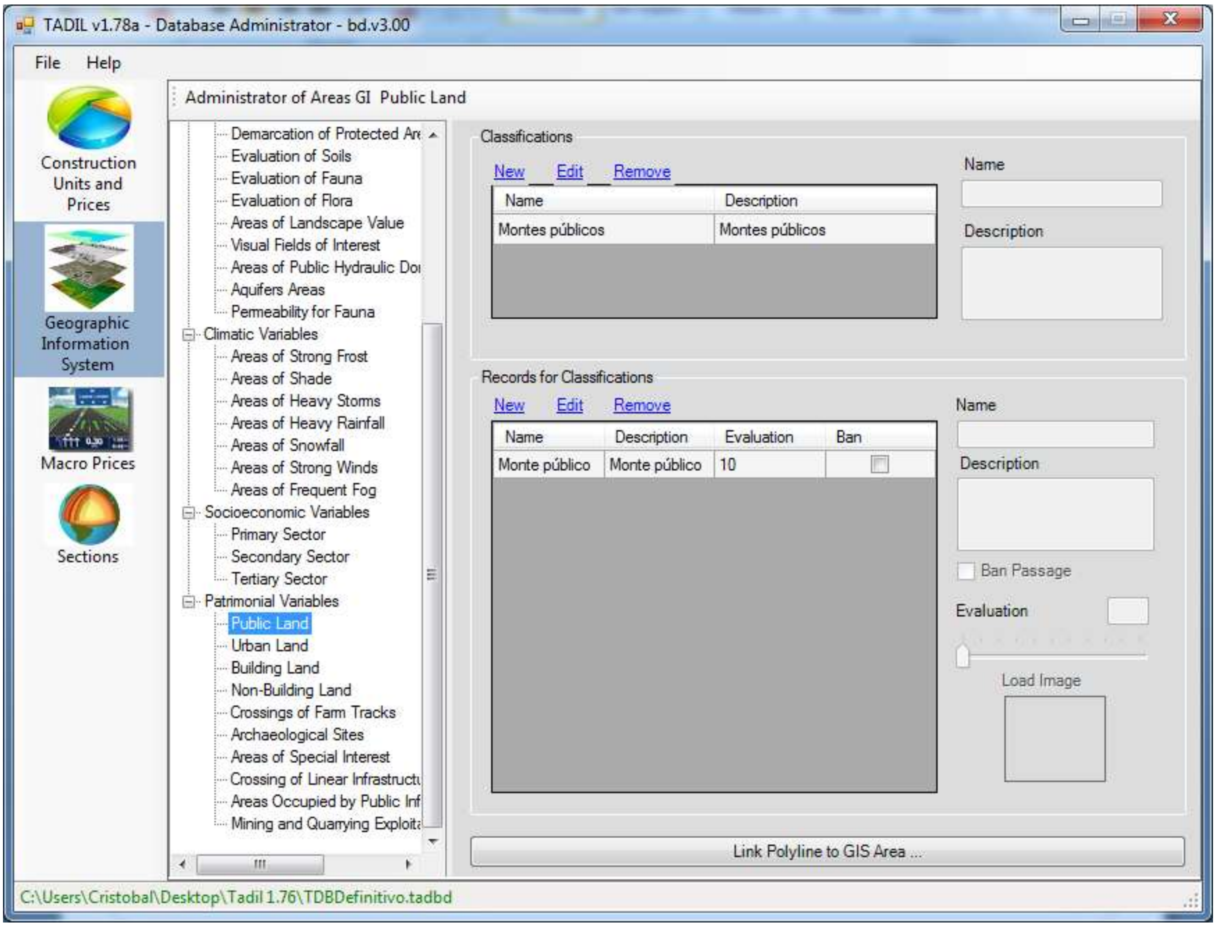


Image 2-60. Software architecture of the Public Land Menu.

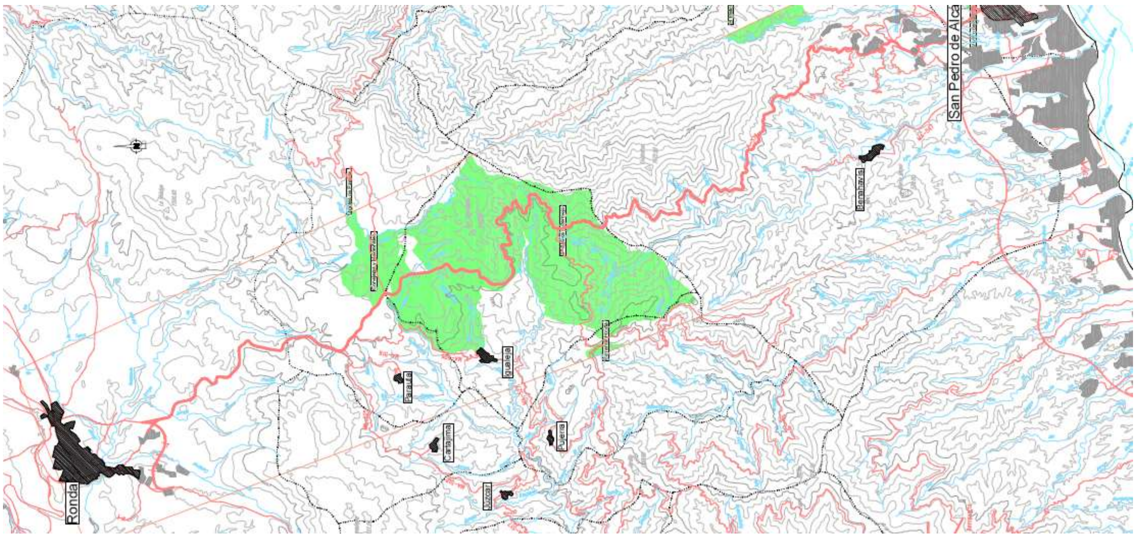


Image 2-61. Example of demarcation of areas of Public Land.

1.2. Urban Land

This includes both consolidated urban land and non-consolidated urban land. The user will be able to indicate the banned areas or select the type that allows applying an expropriation price. This price includes the real estate value of the land and the buildings included in it. It also includes the cost of the demolitions and dismantling of services and machinery that could be required.

The previous cost will be added, in its case, to the production cost indicated in the socio-economic variables.

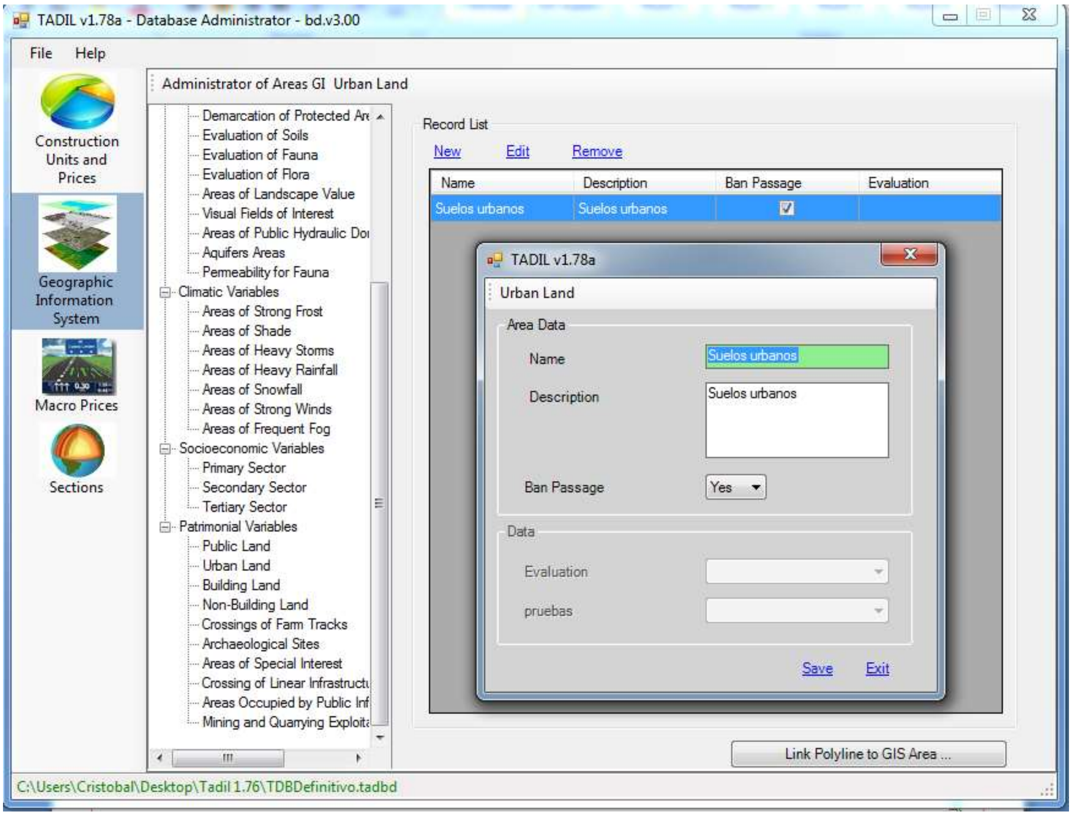


Image 2-62. Software architecture of the Urban Land Menu.

It is worth mentioning that the subjective evaluations that are included must be in line with the patrimonial value of the sector or area that is being defined.

1.3. Building Land

Similarly, all the possible classifications of building land are included. The economic evaluation of the lands can also be performed by inserting a code or designation from the prices database of the software, in order to calculate the cost of an expropriation.

The user can create evaluations that are in line with the different categories of building lands, or indicate banned areas.

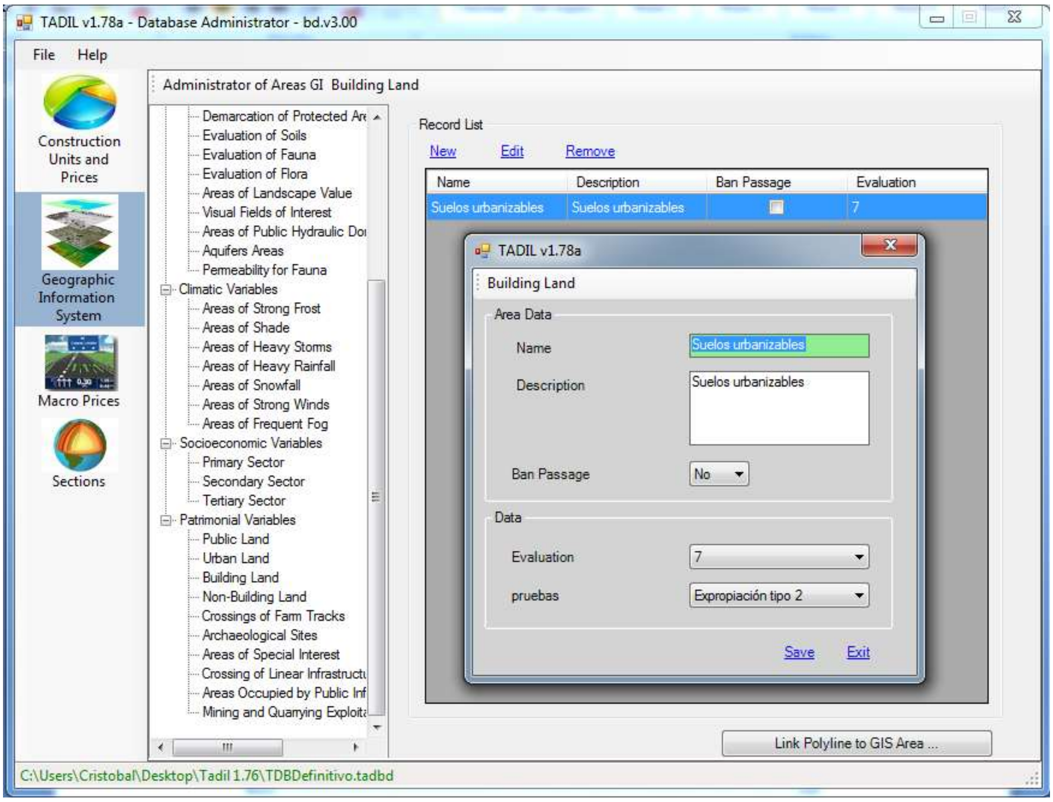


Image 2-63. Software architecture of the Building Land Menu.

1.4. Non-development Land

Likewise, the user can determine the cost of the expropriation of plots of land, that will be added to the cost of the expropriation due to productivity. The subjective evaluation corresponds to the patrimonial value that is being considered.

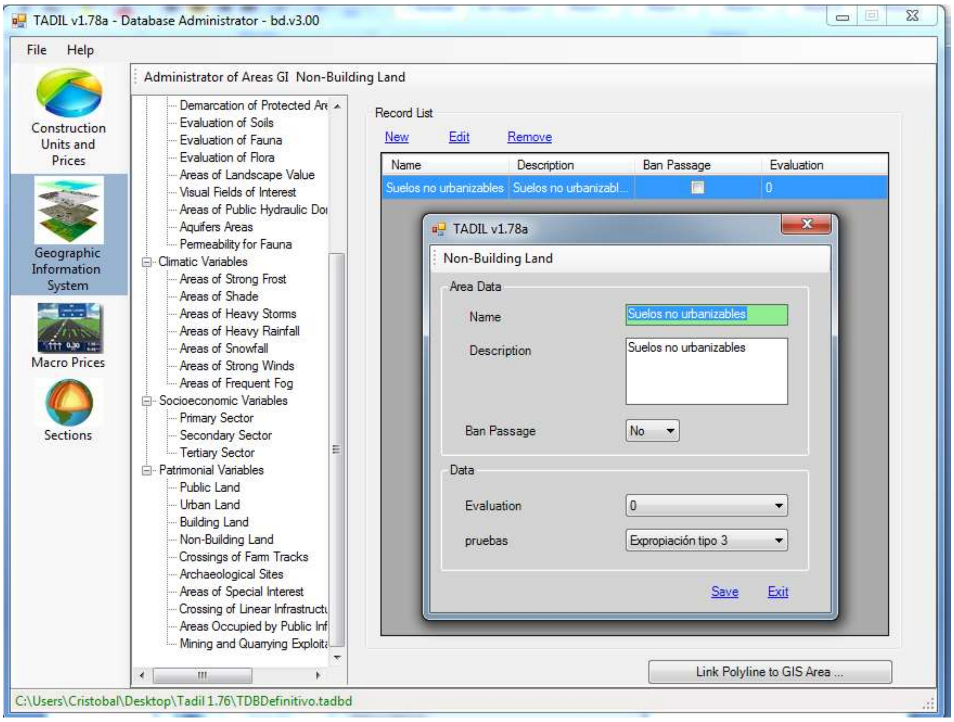


Image 2-64. Software architecture of the Non-development Land Menu.

1.5. Demarcation of archaeological sites

The software also allows the creation of subclassifications, because there are many types of archaeological sites: according to the level of protection (Places of Cultural Interest, Protection areas, Caution areas), according to the type (Prehistoric, Roman), etc.

The user can indicate the banned areas.

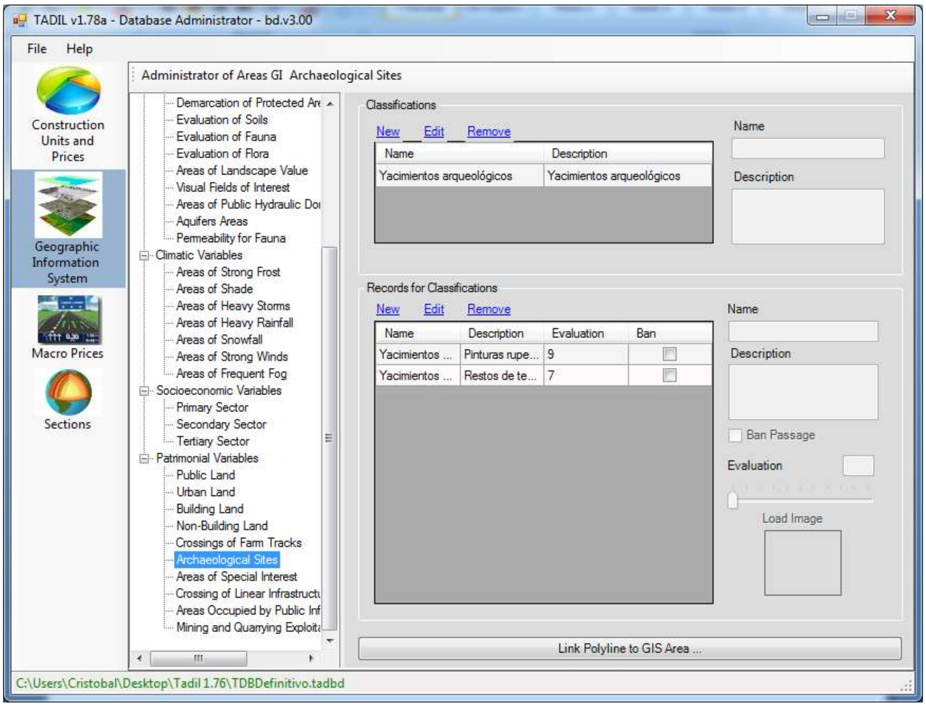


Image 2-65. Software architecture of the Archaeological Sites Menu.

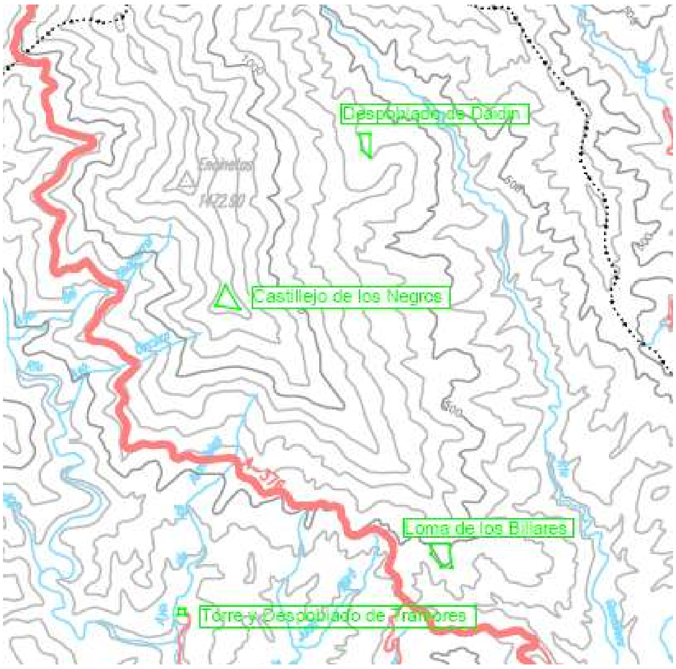


Image 2-66. Example of localization of archaeological sites.

1.6. Demarcation of Areas of Special Interest

This comprises the areas of Special Strategic Interest included in land plannings or infrastructure plannings that have not yet been materialized, such as logistic areas, spaces reserved for infrastructures, areas for installing solar energy farms, etc.

In this case, the economic evaluation of the land is not included by inserting codes; the evaluation is exclusively subjective.

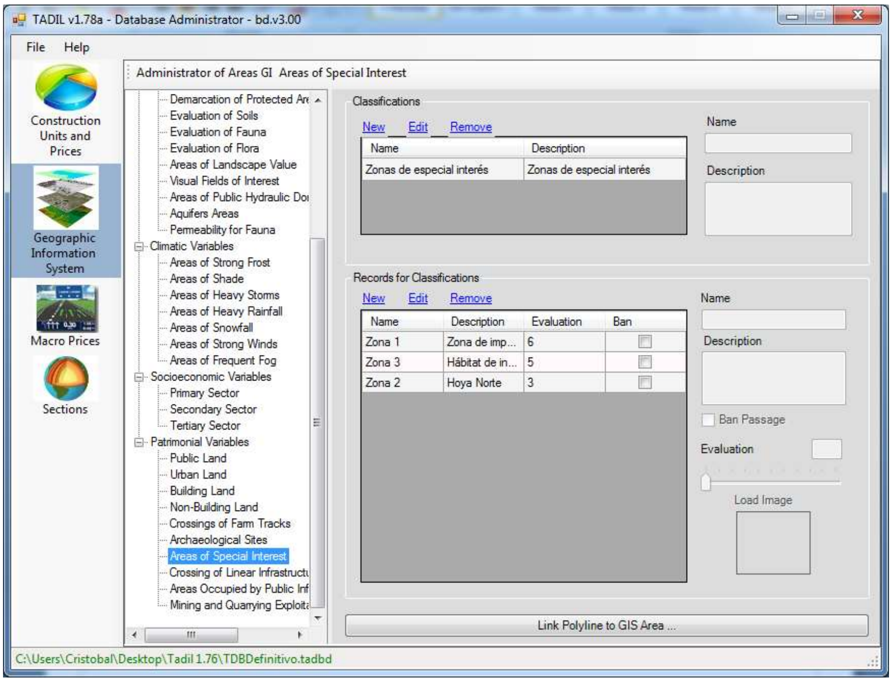


Image 2-67. Software architecture of the Areas of Special Interest Menu.

1.7. Crossing of farm tracks

In the same way as for archaeological sites, the user can create subclassifications, such as trail, thoroughfare, cattle track, etc.

The level crossing of farm tracks and infrastructures is always allowed.

Similarly, the subjective evaluation considers the type of the farm track and takes into account the number of farm tracks that are crossed.

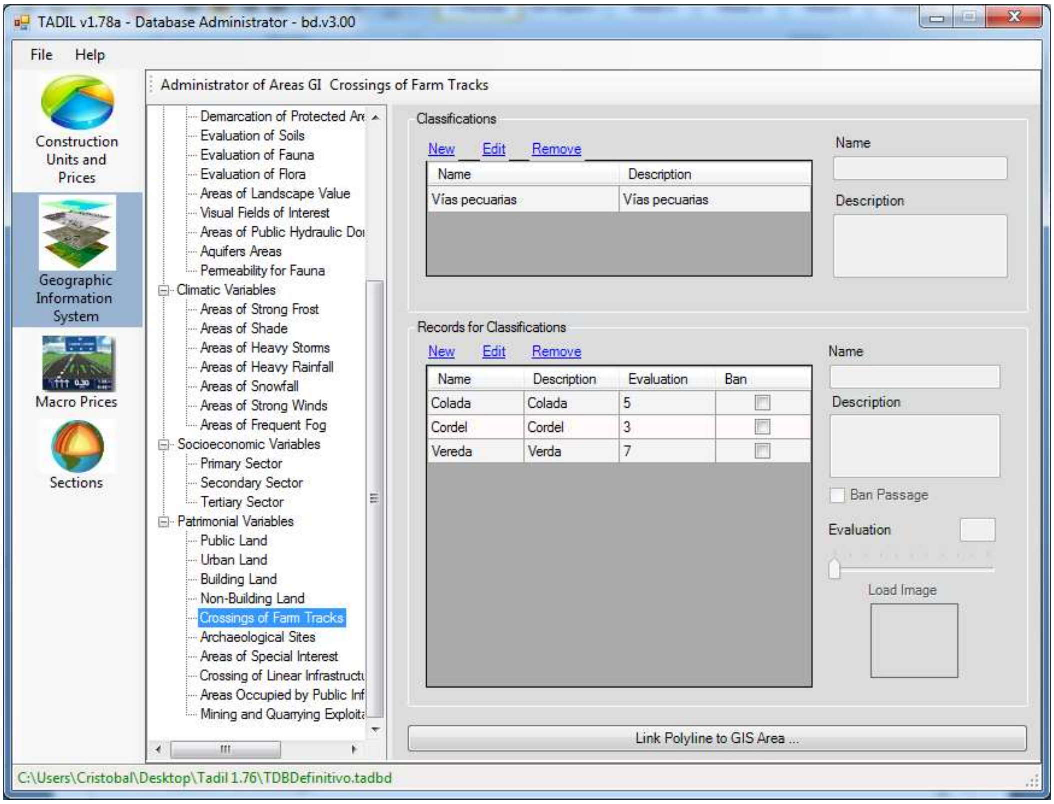


Image 2-68. Software architecture of the Farm Tracks Menu.

1.8. Crossing of linear infrastructures

As in the case of farm tracks, linear infrastructures can be classified into different groups (roads, canals, railways, etc). Therefore, there are different classifications in the menu.

Similarly, the subjective evaluation considers the type of the infrastructures and takes into account the number of crossings.

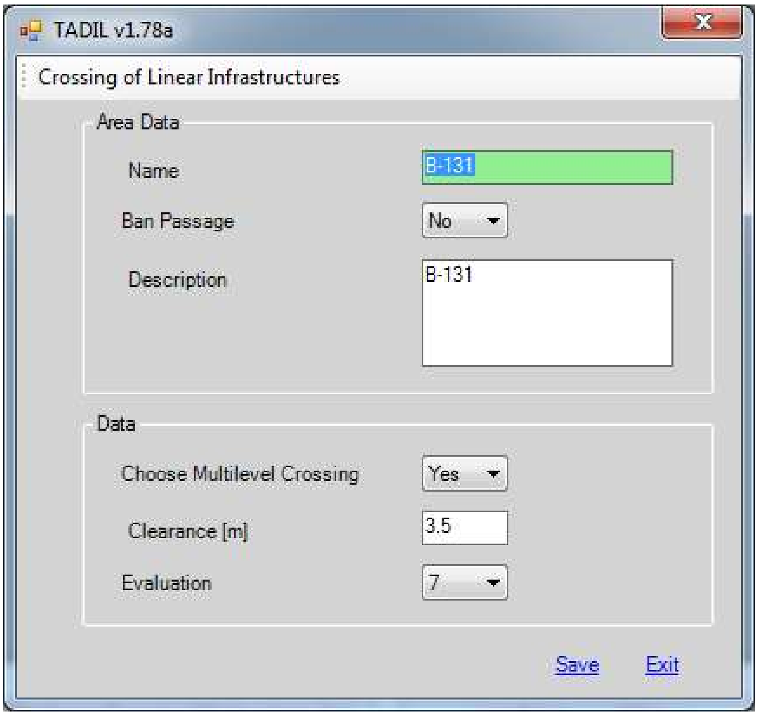


Image 2-69. Software architecture of the Linear Infrastructures Menu.

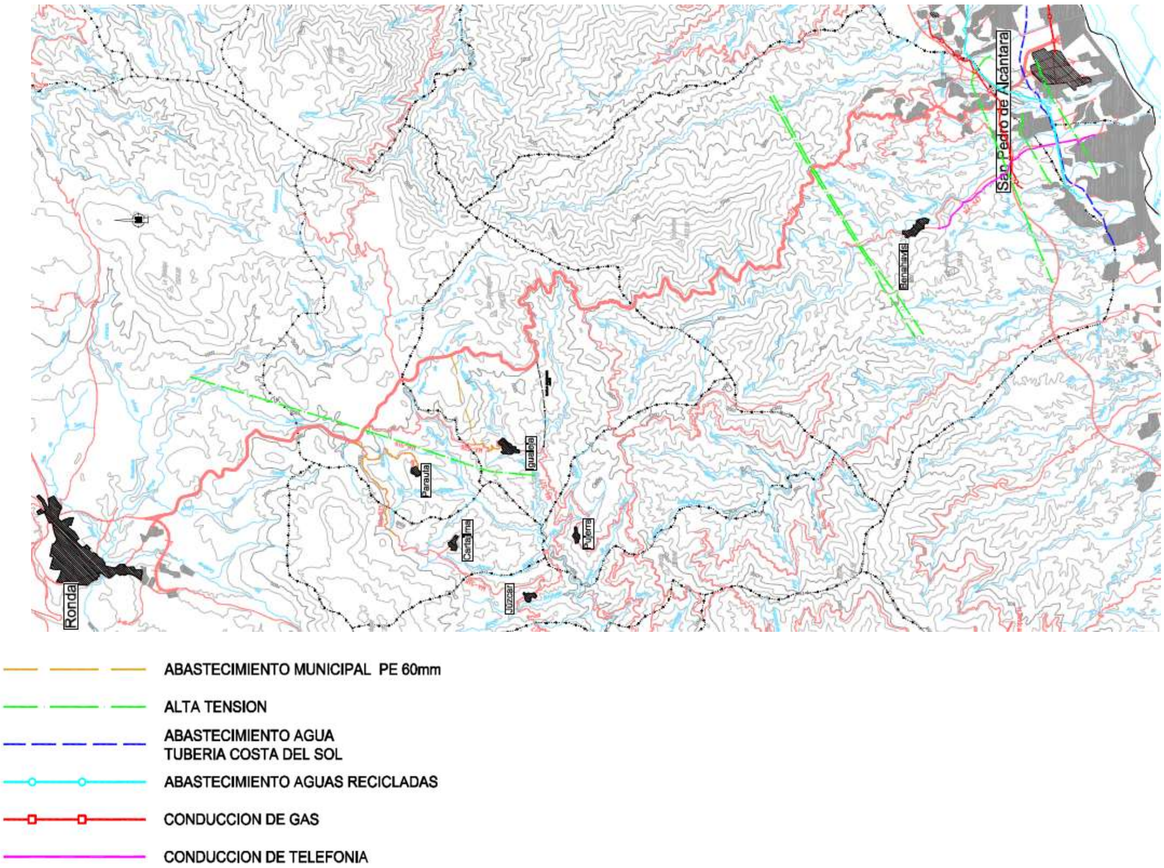


Image 2-70. Example of definition of linear infrastructures.

1.9. Areas occupied by public infrastructures

This variable of the GIS refers to public infrastructures that cannot be considered linear, such as airports, dams, sewage works, drinking water treatment plants, etc.

The user can indicate the banned areas or assign a evaluation.

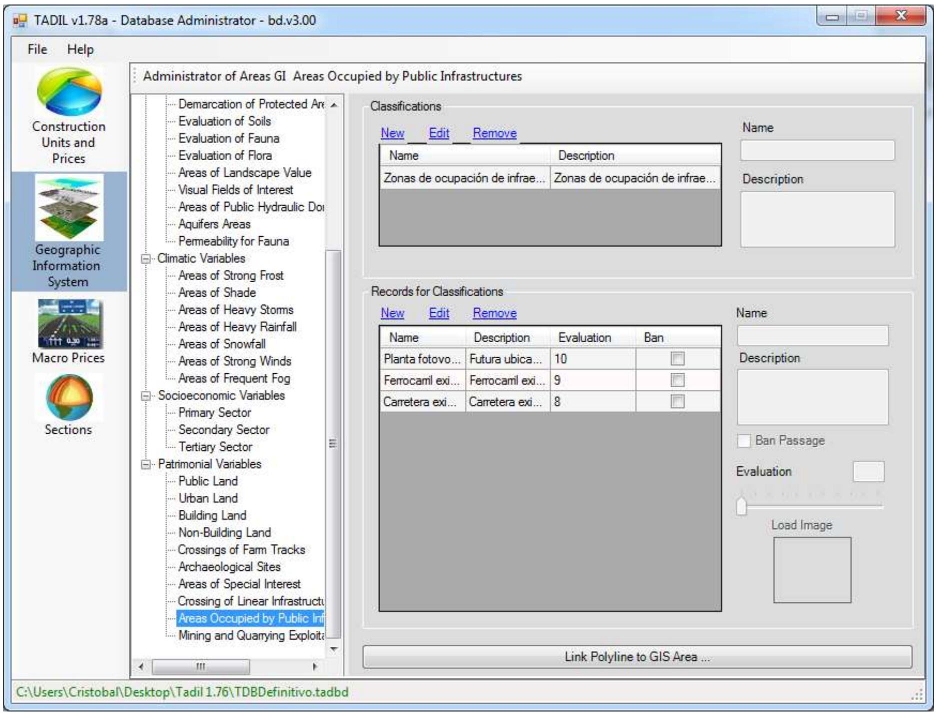


Image 2-71. Software architecture of the Non-linear Public Infrastructures Menu.

1.10. Mining exploitations

Mining exploitations are considered an independent variable due to the peculiarity of the current legislation in several countries, where mining exploitation rights can be obtained over certain areas without owning the land. Therefore, we can identify two areas that are clearly differentiated:

- Areas that are exploited: mines or quarries
- Areas that are not exploited, but have accepted exploitation rights

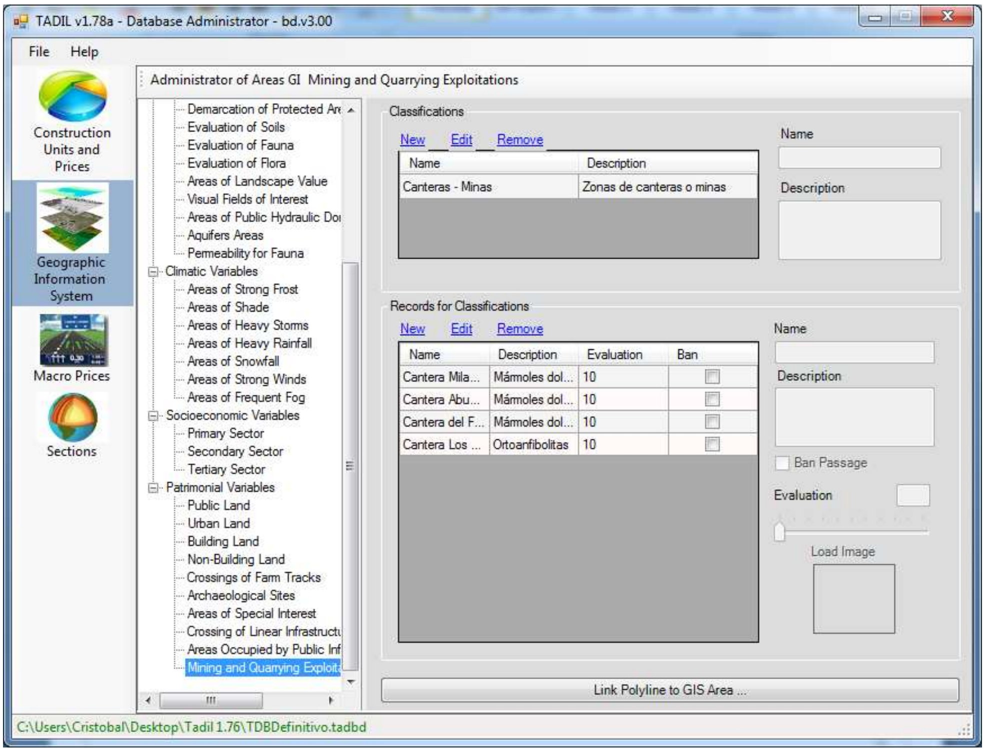


Image 2-72. Software architecture of the Mining Areas Menu.

GEOGRAPHICAL INFORMATION SYSTEM

SUB-CHAPTER 8. STRUCTURES

0. Introduction

In this chapter, the last group of variables is described: structures. Their definition determines the qualitative evaluation of the solutions and the budget of the alternatives.

1. Structures

The Structures files are defined in a similar way as the Geotechnical files, allowing the definition of a general file for the whole territory and specific files for smaller areas.

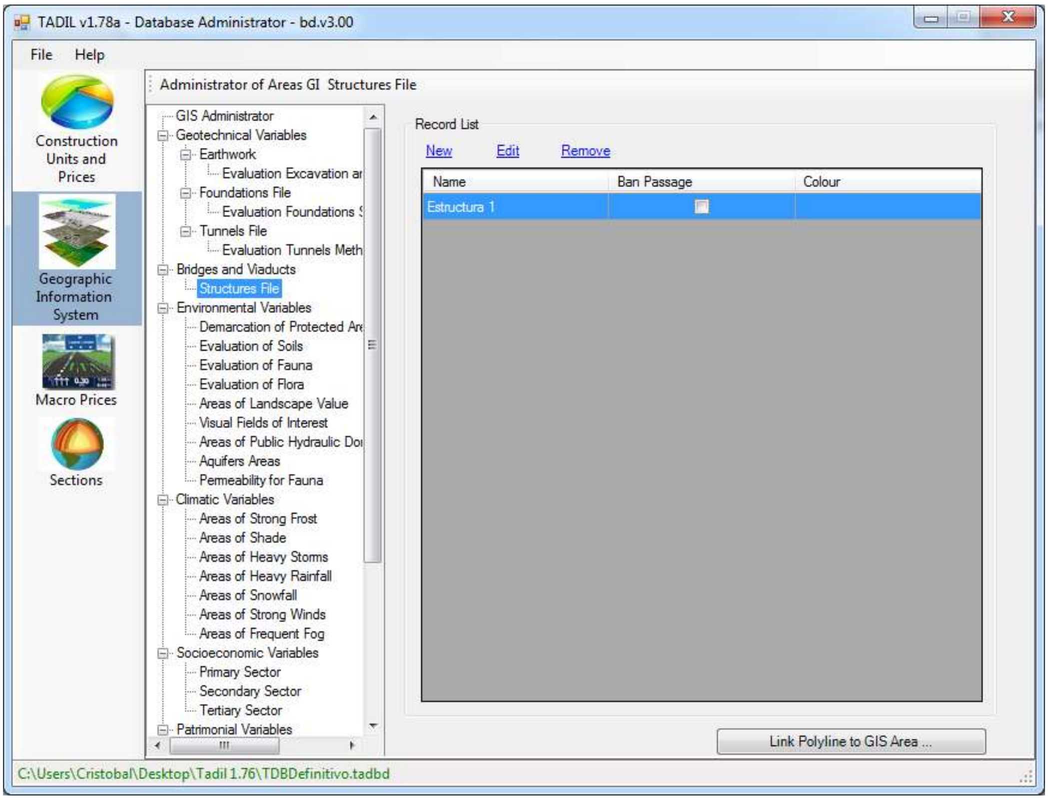


Image 2-73. Selection of general or specific file.

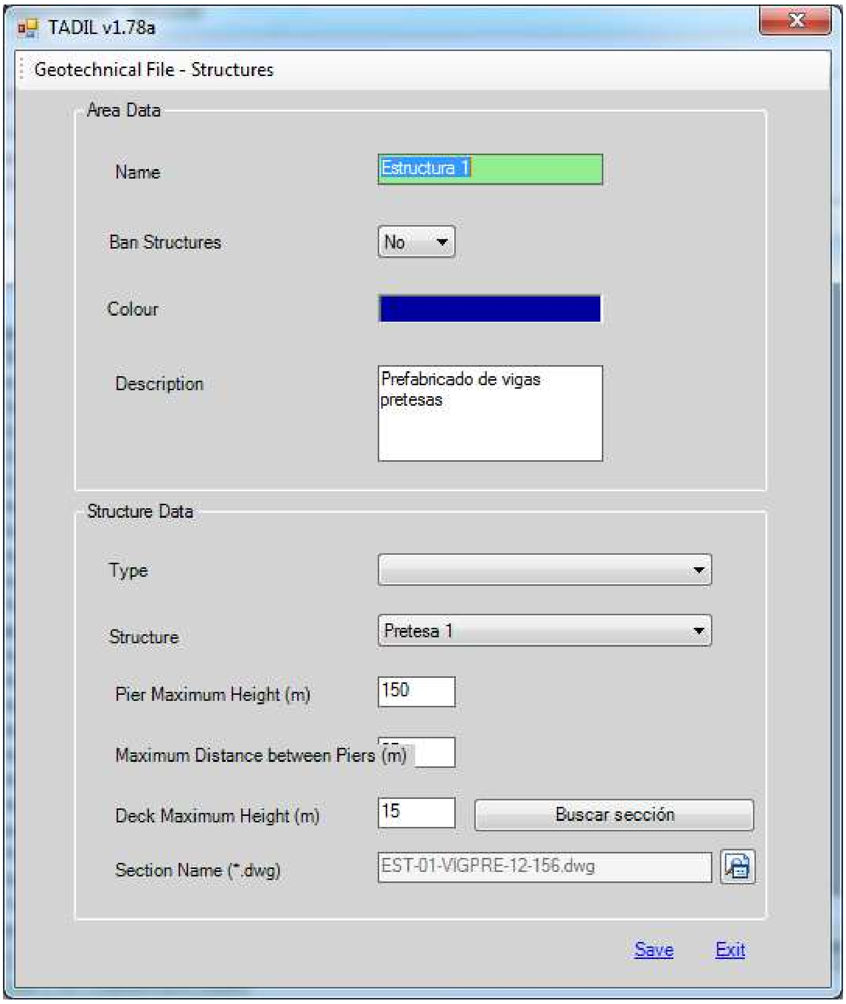


Image 2-74. Software architecture of the Structures Menu.

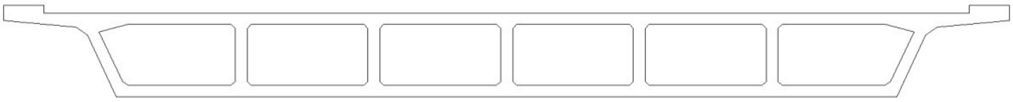
In the Structures file, the user will be able to control the maximum admissible height of the pier or simply block the creation of structures.

A price will be given to the type of the selected structure by assigning a code or name from the Construction Units Database.

The software offers the following types:

- Prefabrication of pre-tensioned beams
- Voided concrete slab reinforced on site
- Voussoir
- Mixed structure or mixed structure with arch
- Post-tensioned on site with variable edge
- Post-tensioned on site with continuous edge
- Cable-stayed bridge with central pylon
- Cable-stayed bridge with upper arch
- Arch below deck with vertical trusses

The user must indicate the distance between piers for the longitudinal representation, and the width of the deck for representing its corresponding cross sections.



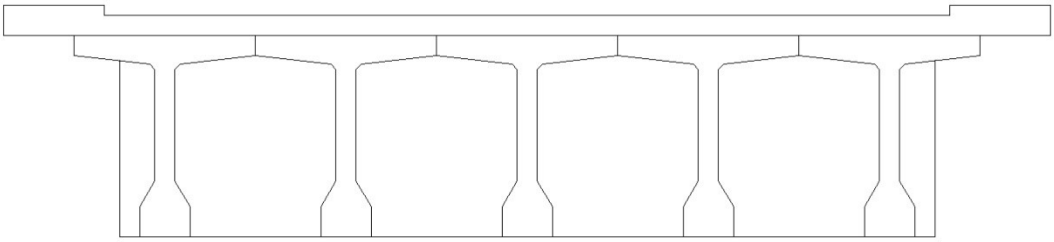


Chart 2-3. Examples of type sections implemented in the software.

GEOGRAPHICAL INFORMATION SYSTEM

SUB-CHAPTER 9. THEMATIC PLANS

0. Introduction

In this chapter, some aspects related to the creation of thematic plans and the input of thematic areas are described.

1. Implementation of the areas

A good definition of the territory's GIS requires a fine previous delimitation of all the areas. Ideally, the thematic layers will already be drawn out in CAD format, including the different areas that want to be implemented. With this previous work done, all that is needed is to select the corresponding polylines for their integration in the GIS of the TADIL software.

2. Creation of thematic plans

The plans are edited according to the classifications defined in each variable (for instance, "Protected mammals", "Protected invertebrates" or "Protected birds" in the variable "Fauna"). Each classification generates a layer in cad able to be edited for making thematic plans.

The input of images in some of the variables allows their representation in the thematic plans. The image will appear in the centre of the designated area.

The following images show the menus generated in the TADIL software for inserting the GIS variables.

It is very important to do the following:

If the user, by mistake, draws two overlayed areas inside a variable (for example, geotechnical areas, area 1 and 2), TADIL will assign the area of smaller surface to the point inside the insertion.

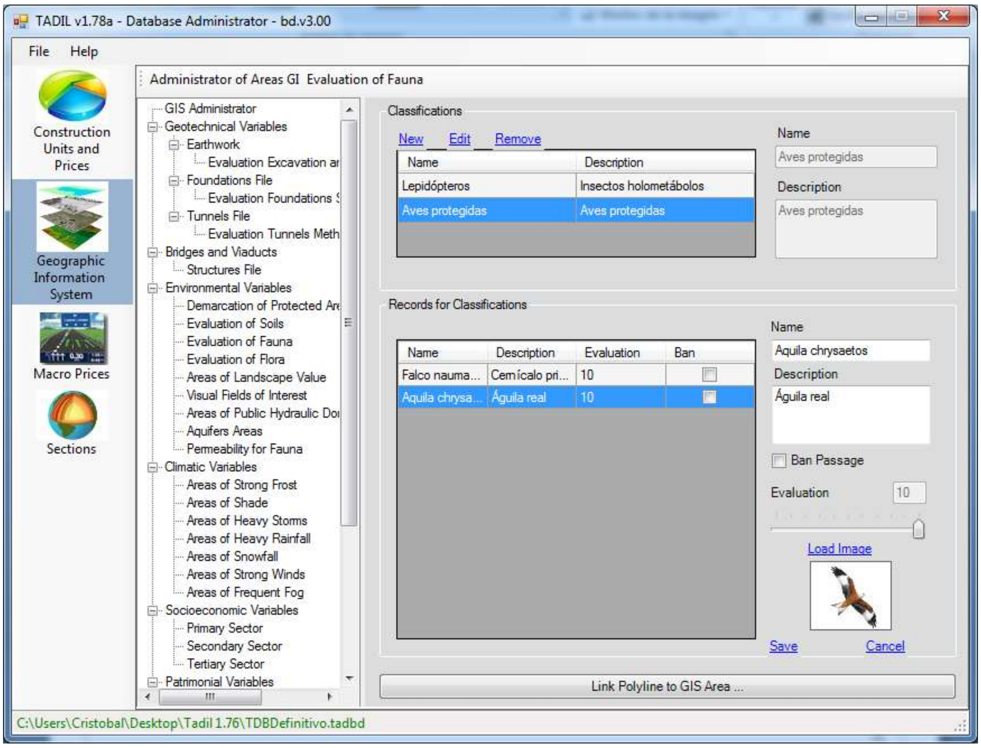


Image 2-75. A menu is generated for assigning images to the variables.

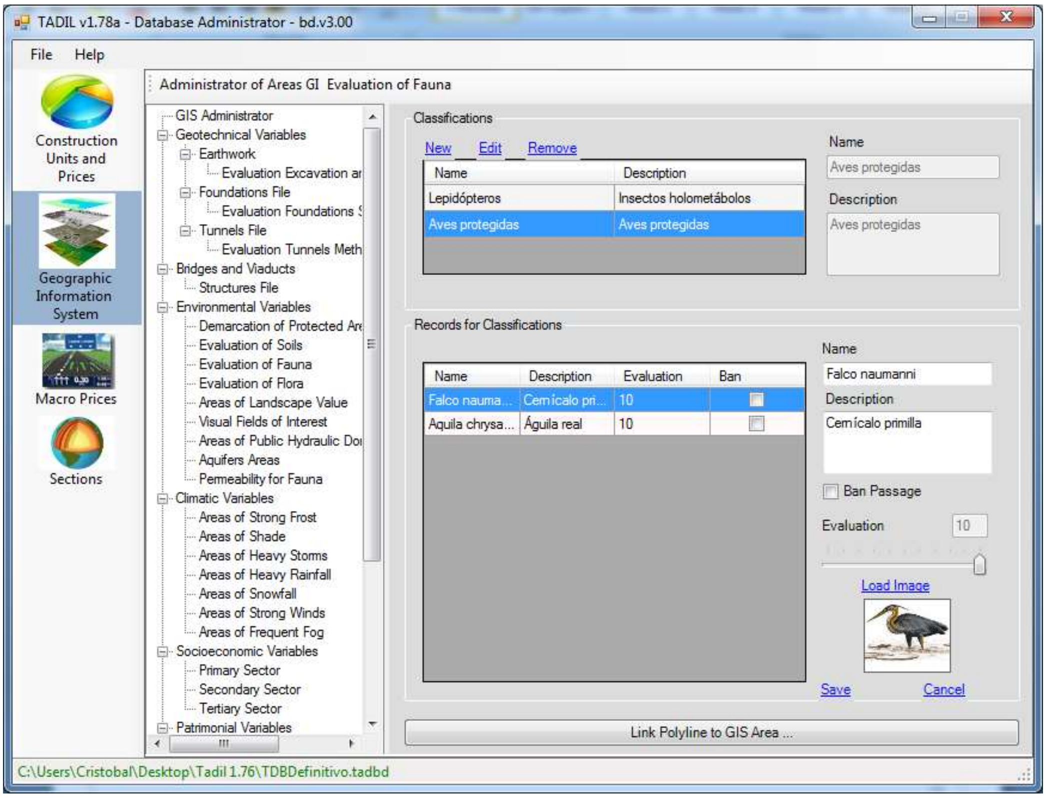


Image 2-76. The creation of areas is included in the submenu for each variable.

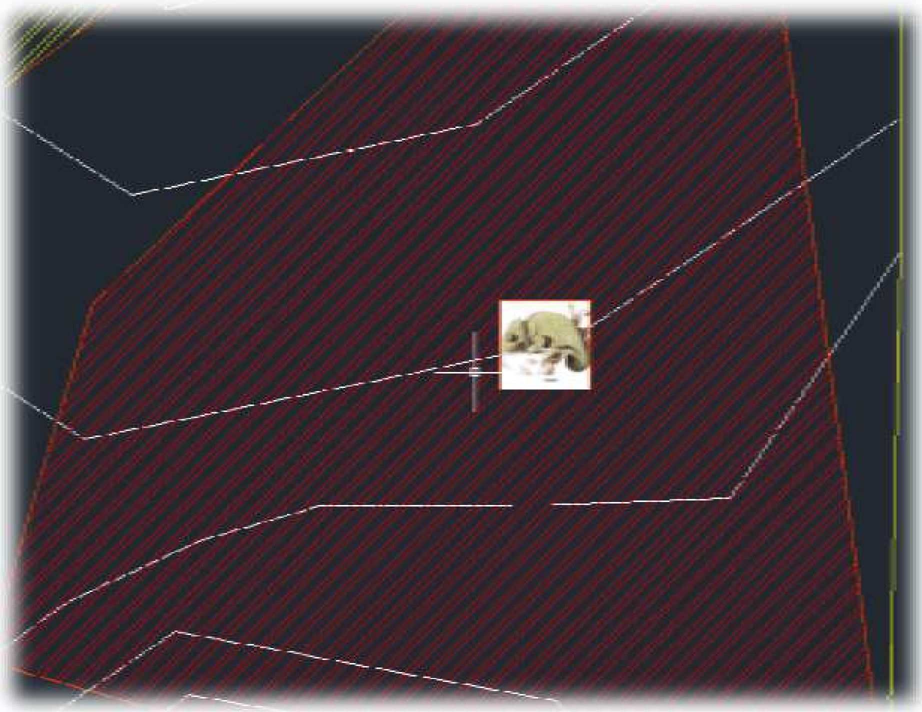


Image 2-77. The icon appears represented in the polygon or application area of the variable.

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES (TADIL)

CHAPTER 3. CONSTRUCTION UNITS AND PRICES

GUÍA METODOLÓGICA DE APLICACIÓN

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES

Methodological Application Guide

CHAPTER 3. CONSTRUCTION UNITS AND PRICES

EDITION 1

This chapter describes the construction units used when configuring the budget of each of the route alternatives of the linear infrastructure, as well that of the solution that is finally selected.

The program allows obtaining a budget as part of an Informative Study, not a complete project budget. Therefore, budget items are defined with a macro-price. In both cases, the program allows obtaining a comprehensive report of the earthwork (cuts, excavations, fills and scalings) and the measurement of walls, ditches and pavements. These measurements allow obtaining the earthwork balance, that is to say, the difference between the volume of excavated materials and the volume of materials used for fill sections and embankments. This will determine whether or not borrow pits (from quarries or land exploitations) and landfills will be needed. This information is essential for calculating the budget and determining the feasibility of the construction work.

CONSTRUCTION UNITS AND PRICES

SUB-CHAPTER 0. PROCEDURE.

0. Introduction

In this chapter, we describe the construction units that configure the budget, as well as the assignment of prices to each of them.

1. Methodology

The input of construction units and their corresponding prices only makes sense when the user wants to create a complete **Informative Study**.

If a Previous Study wants to be created, the user will only have to insert the macro-prices from the Draft Menu. However, when doing so, a budget of the route alternatives or a comparative evaluation between the alternatives cannot be obtained.

In the Construction Units and Prices Menu, there are two groups of construction units:

- A first group of units that allow a comprehensive measurement of the cross section. These are:

- Cut sections
- Excavations
- Fill sections
- Pavement materials coming from treatment plants
- Ditches
- Walls

- A second group of construction units valued with macro-prices. These units are usually divided at a project level, although for an Informative Study a global evaluation will be enough:

- Structures (bridges and viaducts)
- Tunnels
- Drainage
- Signalling
- Replacement of services
- Geotechnical corrections
- Provisional diversions
- Complementary actions
- Corrective measures
- Workplace health and safety

All the construction units with prices or macro-prices include the necessary resources, workforce, machinery, materials, fees, a variety of expenses and indirect expenses for the complete execution of the construction unit.

Finally, the Construction Units Menu also includes the evaluations of the land according to their production capacity and patrimonial value. Both of these variables allow estimating the cost of the expropriations of a linear construction work.

2. Influence on drafting

As indicated above, the construction units and their corresponding prices only have an influence on the automatic design of route alternatives when the user enables the option "Informative Study". In the option of Previous Study, the user will not be able to obtain the budget of the drafts.

The general and local algorithms for the creation of different routes assess the costs of each point and, based on that, select the best itineraries.

3. Evaluation of route alternatives

When the user wants to create a complete Informative Study, he or she should indicate the construction units needed for the project, with their corresponding prices. This allows the software to carry out the following actions:

1. *Obtaining the budget of each alternative*
2. *Obtaining the earthwork balance*
3. *Creating the corresponding feasibility study*
4. *Evaluating the route alternatives according to investment, earthwork compensation and feasibility.*

CONSTRUCTION UNITS AND PRICES

SUB-CHAPTER 1. GROUP 1 OF CONSTRUCTION UNITS.

MEASURING THE CROSS SECTION.

0. Introduction

In this chapter, we describe the construction units that allow evaluating the units that configure the type section of the linear construction work.

1. Construction units

The construction units that are inserted are the following:

- Cut sections
- Excavations
- Fill sections
- Pavement materials from treatment plants
- Ditches
- Walls

Each of these is described below.

2. Clearings

The clearing is the superficial width of topsoil which is removed and taken to landfill before the excavations or the embankments are created. The clearing produces a line which is parallel to the profile of the natural soil. On it, the defining lines of the profiles of the excavation, embankment, scaling cuts or scaling fills meet.

The user must consider the geotechnical groups inserted in the Geographical Information System (GIS) in order to define as many scaling types as necessary. For instance, a scaling in rock is not the same as a scaling in soil.

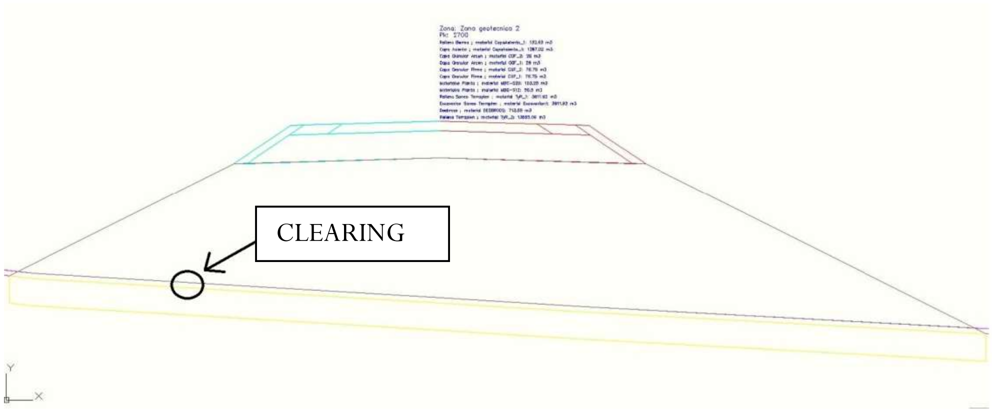


Image 3-1. Diagram of clearing.

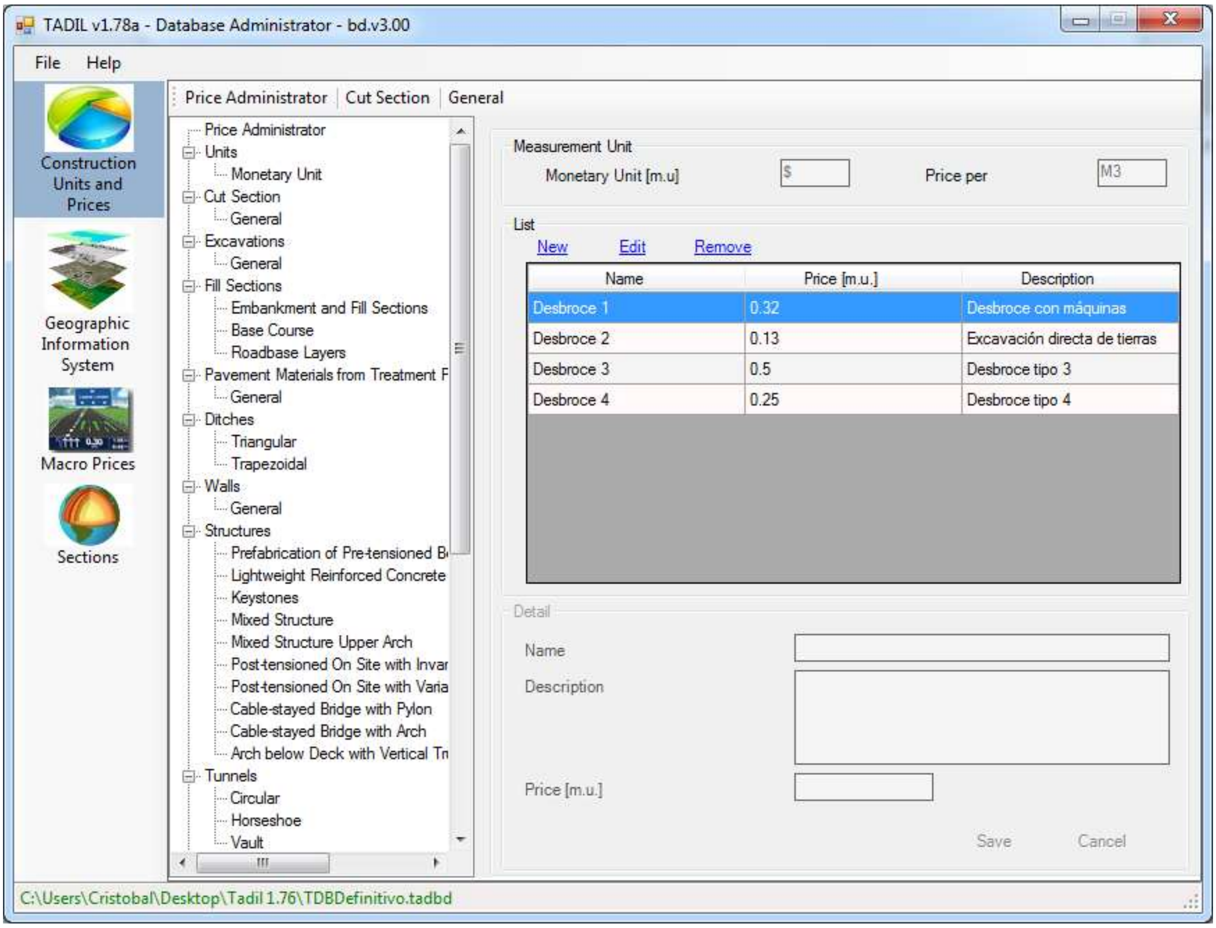


Image 3-2. Menu of clearing.

As opposed to the variables "cut" and "fill", only one price is considered for the clearing, without taking into account the use of the materials in the construction work or their removal to the landfill. The user should ponder both possibilities and give a price valid for both the complete use in the construction work (for slope restoration, for example) and the complete removal to the landfill.

The price of the clearing is given in m^3 and it includes the complete removal to the landfill or to the place of use in the construction work. This price must include the clearing that is generally carried out by a bulldozer (measured per square metre) and the excavation and transport of the topsoil (measured in cubic metres).

3. Excavations

The program allows differentiating between excavation for use at the construction site and excavation for landfill.

Regarding the excavation for use at the construction site, the resulting material is used to fill in granular layers, base courses, embankments or scaling fills. In the excavation, the material left over or that cannot be used in the site, goes to the landfill.

The program creates the earthwork balance automatically according to the indications given by the user in the Geotechnical Files Menu of the GIS. The program takes into account the hierarchy of the materials that will be needed according to the following order:

granular layers → *base courses* → *embankment layers or scaling fills*.

Therefore, if an excavation produces gravel that is used for the granular layer, the gravel left over can be used for the base courses, embankment layers or fill sections.

The excavated materials that are used in the construction site first complete the granular layers, then the base courses and, lastly, the embankment layers and the fill sections.

As a result, it is important that the user pays close attention to the geotechnical groups involved in the area of study, analysing the materials that can be produced in the excavations. Based on this analysis, the user must define an adequate strategy so as to use the maximum amount of materials from the excavations, in order to optimize the construction work. Consequently, if we know that most of the excavated material is tolerable and that only a small part is adequate soil or the selected soil, adequate soil should not be placed in the embankment layers, because most of the excavated materials would end up in the landfill.

The user must arrange the pavement and base courses, the underlying natural soil and embankment, according to the available materials.

In the earthwork balance, the excavated material that goes to the landfill is affected by the Coefficient of Swelling to obtain the total volume, whereas the material used in embankments and fill sections is affected by the Transfer Coefficient to Field.

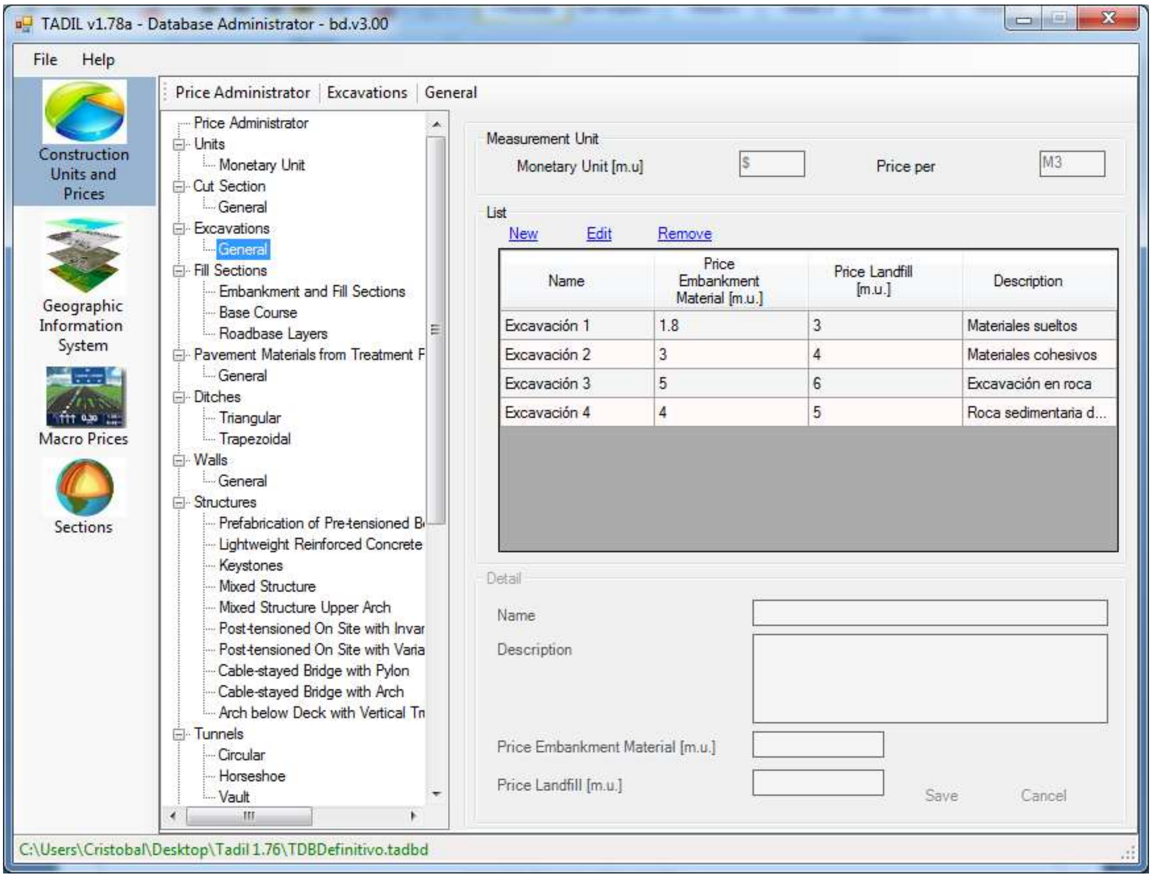


Image 3-3. Excavation Materials Menu.

3. Fill sections

In the Fill Sections Menu there are three sub-menus: Embankments and Fill Sections, Base Courses and Pavement Granular Layers.

There is also a difference between excavated material and borrowed material. The excavated material is the material used in the construction work that is obtained from excavations in the construction work itself, while the borrowed material comes from quarries or other exploitations outside the construction work.

The program automatically creates the earthwork balance according to the information inserted by the user in the Geotechnical Menu of the GIS, thus assigning the corresponding prices to the amounts of fill sections made up of excavated materials or borrowed materials.

This distinction is made for the granular layers, the base courses, the embankments and the scalings of fill sections.

The excavated materials that are suitable for their use in the pavement granular layers usually require a preliminary treatment (in a crushing plant, for instance). The user must assign different construction units to this type of material, assigning a price according to the required technical means and materials.

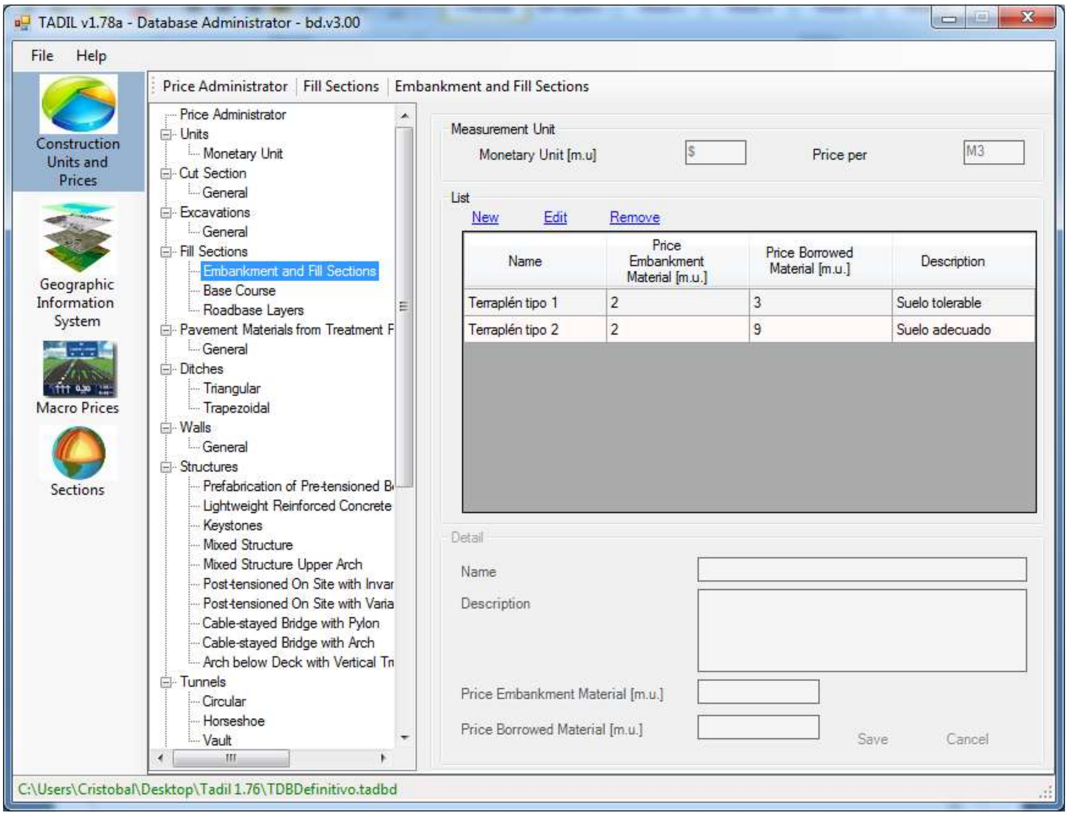


Imagen 3-4. Fill Sections Menu.

4. Pavement materials coming from treatment plants

These are pavement materials that require a previous processing in a treatment plant, and usually include a binding agent such as concrete, aggregate, paving, etc. The granular layers such as aggregate, macadam, gravel and sand are not included. These should be inputted in the specific Granular Layers Menu.

This also includes the materials made on site, in a mobile plant. The user must calculate the costs of the components of each material and their origin, the transportation costs from the factory, as well as their laying, extension and execution in the construction work. When needed, this also includes all the preliminary and final treatments for finishing the layer (such as tack coats, prime coat, superficial siliceous treatment in printed concrete, etc.).

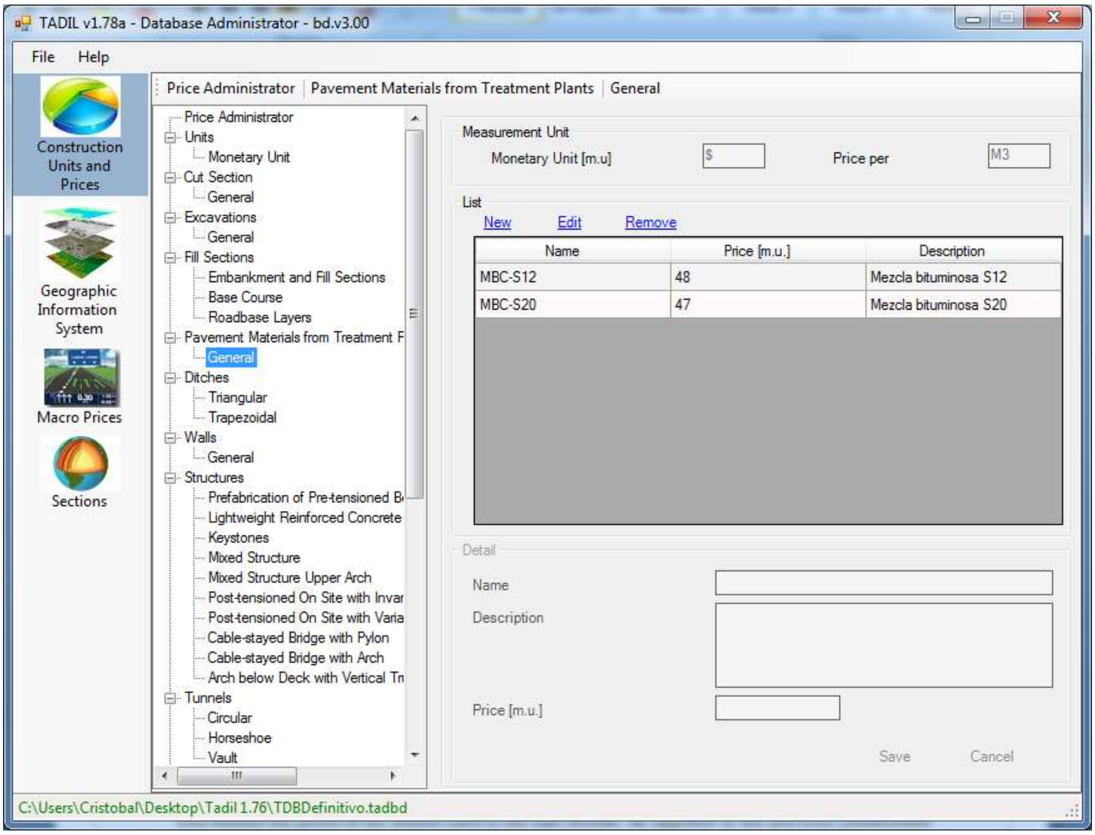


Image 3-5. Menu of pavements coming from treatment plants.

5. Ditches

This defines the prices of the ditches used in the type section. As opposed to the previous construction units, the ditches are defined in the cross section, which is the same for the whole project. Therefore, it is not a variable that depends on the GIS.

The software allows distinguishing between the construction units of triangular ditches and those of trapezoidal ditches.

In all cases, the user must ensure that the construction units include all of the materials, machinery, human resources, auxiliary units and indirect costs for the complete execution of the construction work.

This menu also includes the ditches of the central reservation of double roads. The user can choose a triangular or trapezoidal shape.

Image 3-6. Different types of ditches and their execution.

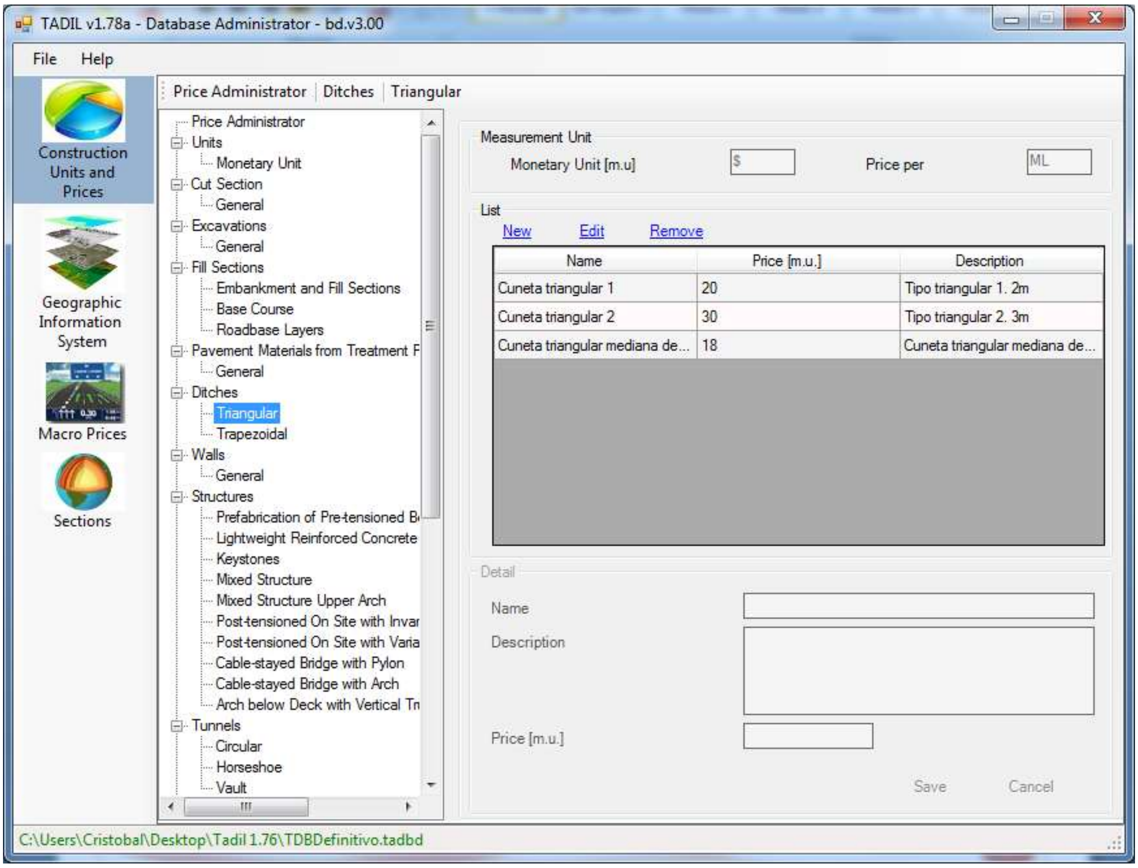


Image 3-7. Menu for the creation of ditches.

6. Walls

These construction units are inputted in the GIS within the Geotechnical Files, in the configuration submenus of cut and fill sections.

These menus define the geometry for each cross section of the walls. Similarly, the construction unit that defines the type and price of the wall is selected.

The software allows choosing from among the construction units generated in this menu.

The user can define as many types as he or she wishes.

Image 3-8. Different types of walls.

CONSTRUCTION UNITS AND PRICES

SUB-CHAPTER 2. GROUP 2. CONSTRUCTION UNITS WITH MACRO-PRICES

0. Introduction

This chapter describes the construction units that are defined and budgeted with a global price that includes all the necessary units for its execution.

This global price or macro-price is based on the existing experience of the specific type of construction work that is defined and for the geographical area where it is to be executed.

This global evaluation allows approaching the cost of the construction work, but it does not produce a comprehensive budget, as in the project. The user must provide all the knowledge and experience possible, and have a solid base of information for defining these macro-prices.

The TADIL software provides an extensive database, considering different types of structures, tunnels and linear infrastructures in general, that may be useful for the user.

1. Construction units with macro-prices

The construction units that are defined with macro-prices are as follows:

- Structures (bridges and viaducts)
- Tunnels
- Drainage
- Signalling
- Replacement of services
- Geotechnical corrections
- Provisional diversions
- Complementary actions
- Corrective measures
- Workplace health and safety

In turn, the groups of structures and tunnels are subdivided into different types as follows:

- Structures (viaducts):

  - Prefabrication of pre-tensioned beams
  - Lightweight reinforced concrete slab
  - Voussoir
  - Mixed structure of steel and concrete
  - Mixed structure with upper steel arch

- Post-tensioned on site with invariable edge
- Post-tensioned on site with variable edge
- Cable-stayed bridge with central pylon
- Cable-stayed bridge with upper arch
- Arch below deck with vertical trusses for strain transmission

- Tunnels:

  - Circular tunnels
  - Horseshoe tunnels
  - Vault tunnel

Below is a description of each of these construction units.

3. Structures

The types mentioned above are described here. In each type, the user will be able to create as many sub-types as he or she wishes. The evaluation of the construction unit is carried out in square metres, and the cost corresponds to the Real Execution Budget. For instance:

Name: Prefabrication of beams TYPE 1.

Price: 800 €/m^2

Description: Viaduct of prefabricated beams with a maximum span of 30m and a maximum pier height of 25m.

In each case, the user must consider the characteristics of the viaduct that allow its configuration in the GIS. For instance, if the orography is very difficult and the user decides to allow a deck height of up to 60m, the cost of the same type of viaduct is not comparable if the piers are limited to 25m. Therefore, the definition of prices must be coherent with the design needs determined by the geomorphologic characteristics of the territory.

The software allows importing the type section of the represented structure with the set of cross sections.

Here is a brief summary of the characteristics of each type:

- Prefabricated bridge with pre-tensioned beams

These are viaducts with prefabricated pre-tensioned i-section beams and box girder. The beams are produced in the prefabrication centre and mounted on supports on site (on neoprene bearing pads, for example). The deck is built on top of these beams.

Image 3-9. Different types of prefabricated bridges with box girder beams or i-section beams.

- *Lightweight reinforced concrete slab*

These are reinforced concrete decks built on site that include longitudinal voids. Usually, if there is no post-tensioned steel, the maximum length of the span is limited.

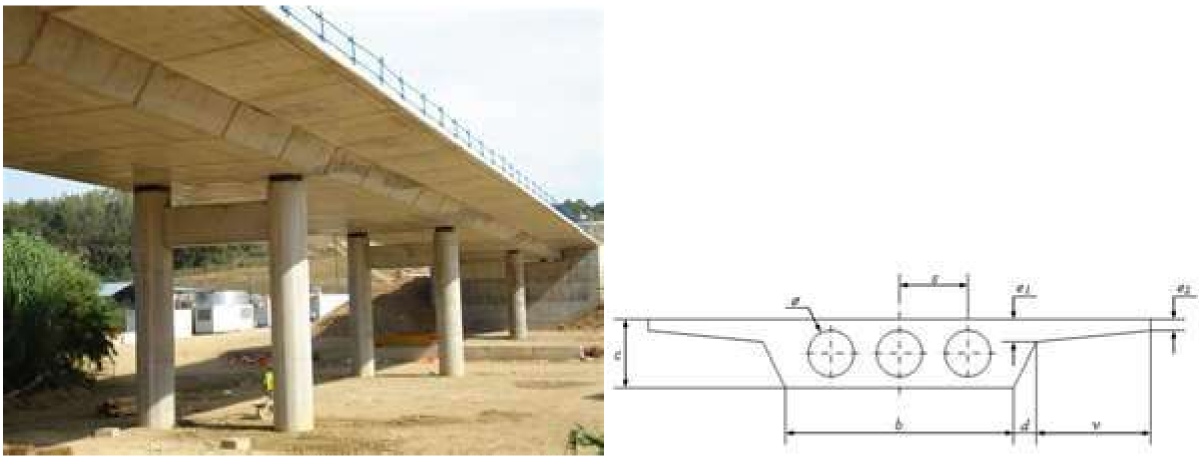


Image 3-10. Example of slab bridge made with circular voids.

- Voussoir

The deck is configured by joining concrete prefabricated sections which are later joined on site by means of post-tensioned cables.

Image 3-11. Example of slab bridge made with circular voids.

- Mixed structure of steel and concrete

These are structures in which the concrete deck lies on a steel structure made of longitudinal beams, box or metal lattice which is, in turn, on the piers. In the case of lattices, the metal structure usually has traditional configurations, such as the Watt beam. They used to be very abundant in railway infrastructures, but are now less used for roads on bridges with a large span made by pushing outwards from the abutment.

Image 3-12. Mixed structures with metal beams, lattice and box.

- Mixed structure with upper steel arch

As opposed to the previous type, in this case the metal structure is arranged reaching a height above the deck from which it receives the permanent and usage loads, through beams and braces that connect with it. The longitudinal profile of the metal structure usually corresponds to the geometry of the arch that lies on the piers that delimit it.

Image 3-13. Different solutions of mixed structures with upper arch.

- Post-tensioned on site with invariable edge

As opposed to the lightweight reinforced concrete slab bridges, the bridges post-tensioned on site with invariable edge include post-tensioned steel with a section formed by longitudinal voids or box-type voids.

Image 3-14. Bridge post-tensioned on site with invariable edge.

- Post-tensioned on site with variable edge

As opposed to the previous type, in this case the lower profile of the edge of the deck is usually parabolic, circular or includes three sections in each span, with an invariable edge in the centre.

As in the previous case, the execution of the bridge can be carried out with different methods depending on the conditions of accessibility and the technical feasibility (centring, cantilever construction from the pier, etc.).

Image 3-15. Bridge post-tensioned on site with variable edge.

- Cable-stayed bridge with central pylon

In this case, the concept of structure changes radically with respect to the previous ones. There is a central pylon that receives the strain of the deck through cables.

This type allows obtaining larger spans, although the cost of the construction work is usually much higher. It is used more frequently for crossing large valleys or wide rivers.

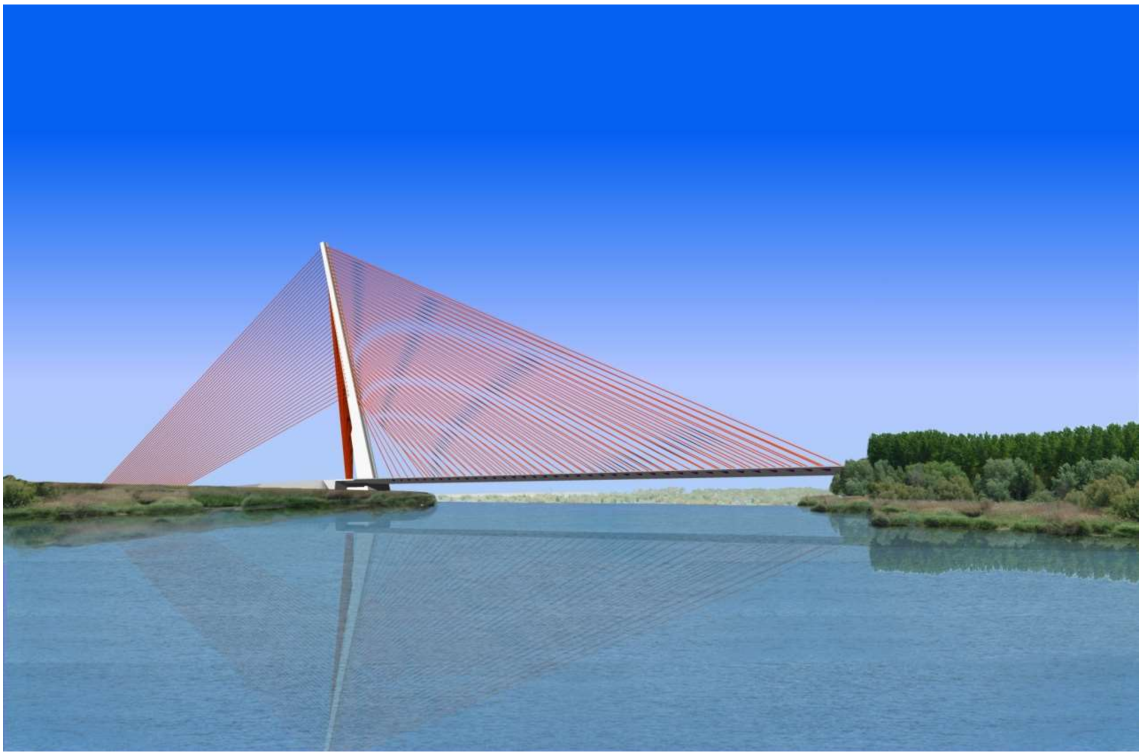


Image 3-16. Cable-stayed bridges with central pylon.

- Cable-stayed bridge with upper arch

As opposed to the previous type, in this case an upper arch receives the strain of the deck through cables.

With this type of bridge, spans of up to 120 m have been obtained.


Image 3-17. Cable-stayed bridge with arch.

- Arch below deck with vertical trusses for strain transmission

Lastly, this traditional type of structure is included, with a lower arch structure below the deck which receives the strain through vertical trusses.

The structure can be made of metal, concrete or mixed.

Image 3-18. Metal arch bridge.



Image 3-19. Arch bridges; upper image with metal arch, lower image with concrete arch.

4. Tunnels

As we mentioned earlier, in the software there are three types of tunnels according to their geometry: circular tunnels, horseshoe tunnels and vault tunnels.

In the GIS Menu, the software allows defining the appropriate type as well as the actions to be carried out on the face of the tunnel, and allows suggesting a support solution according to the RMR value. Moreover, the user can select the desired tunnel lining or choose voussoirs for the circular geometry.

Therefore, the user must take into account the geotechnical characteristics of the territory as well as the construction procedures, because the difference in costs can be significant depending on the solution that is selected.

The macro-price is defined per kilometre of tunnel, including all of the materials, machinery, human resources, auxiliary units and indirect costs necessary for building the tunnel.

Image 3-20. Circular tunnel with voussoirs and voussoir manufacturing plant.

Image 3-21. Different images of tunnels with vault geometry.

Image 3-22. Different images of tunnels with horseshoe geometry

5. Macro-prices that are not linked to the GIS

This section includes conventional cost ratios of complete budget chapters per unit of length of the infrastructure or as a percentage regarding the Real Execution Budget of the construction work.

When assigning these ratios, the user must take into consideration the characteristics of the infrastructure as well as those of the territory.

The ratios are applied equally to all the route alternatives included in the Informative Study once they are activated in the Budget Menu. These prices are therefore independent from the GIS, although when creating them the user must consider if they are adequate for the environment and the type of work.

The budget chapters which will be assigned macro-prices are as follows:

- Drainage
- Signalling
- Replacement of services
- Geotechnical corrections
- Provisional diversions
- Complementary actions
- Corrective measures
- Workplace health and safety

Here is a brief summary of each of the previous budget chapter.

Drainage: This includes all the investment in the linear construction work for the required transverse drainage, longitudinal drainage (not including the ditches), base drainage and channelling. The rainfall, the amount of watercourses and the water flow must guide the user regarding the costs ratio that has to be implemented in the Informative Study.

Image 3-23. Different images of transverse drainage works.

Signalling: This macro-price includes both horizontal and vertical signalling, as well as road signs and boundary milestones. The user will consider a higher cost of this construction unit when frequent crossing of infrastructures is expected.

Image 3-24. Different images of construction work signs.

Image 3-25. Different images of horizontal y vertical road signs.

Replacement of services: This includes all the services affected by the infrastructure: irrigation, electricity, telephone, gas, piping, etc. The user must ponder this variable according to the density of the existing services in the area.

Image 3-26. Different images of replacement of services.

Geotechnical corrections: This includes all the additional stabilisation work that is expected throughout the construction work that cannot be valued according to the defining unities of the cross section, including rip-raps, green walls, hydro-seeding, vibro-compaction of soil, etc.

The user will consider the geotechnics of the soil to evaluate the higher or lower volume of this construction unit.

Image 3-27. Detail of geotechnical correction in slope.

Provisional diversions: The value of this macro-price depends on the volume of linear infrastructures that will be crossed or the degree of coincidence with existing infrastructures.

Image 3-28. Detail of diversion in construction work.

Complementary actions: This group includes all the works related to service roads parallel to the infrastructure or surrounding the construction work. The user will consider the need to plan service roads. Therefore, a construction work in a farming area will be different to that in a forest area. This group can also include construction units that cannot be included in other sections.

Image 3-29. Images of infrastructures with service roads.

Corrective measures: This includes all the actions related to the use of topsoil in slopes and its maintenance during the construction work, marking of soil stockpiles, transplantation of species of trees, dust-control watering on the construction site, previous archaeological field surveys, ponds for collecting oil from machinery, improvement of drainage work for the passage of fauna, wooden panelling of traffic barriers, street furniture in rest areas and lay-bys, etc. The user will consider whether to include these actions and to what degree.

It is important to include in this construction unit all wildlife corridors. When the user has added in the GIS the areas where wildlife corridors are required, the possible economic incidence on the budget must be pondered. In general, wildlife corridors are materialized as false tunnels that are usually over fifty metres long.

Image 3-30. Images of wildlife corridors.

Workplace health and safety: This variable appears as a percentage with respect to the Real Execution Budget of the construction work. The user must take into account that the larger the number of structures and tunnels, the larger the percentage that must be taken into account with respect to the total of the construction work.

Image 3-31. Workplace health and safety signs.

0. Introduction

This chapter describes the construction units that allow evaluating the expropriations that the construction of the linear infrastructure may require.

The occupation of the territory is defined by the surface of the construction work (the edge of the cut or fill sections) plus the margin at each side, determined by the administration. This distance is described in the Budget Menu.

When the user expects having to build service roads, this amount must be increased.

1. Evaluation of production

The expropriation of a productive plot of land, in agriculture, industry or services, entails a rupture of the economic ratios of production of the entity that exploits it. This outcome is usually overlooked in most construction works. The larger the profitability of the exploitation, the larger its impact is.

The user must take into account the local regulations, the way of evaluating the economic loss that is generated and the consequent compensations that must be paid. To do so, the user must consider the map of land uses inserted in the GIS.

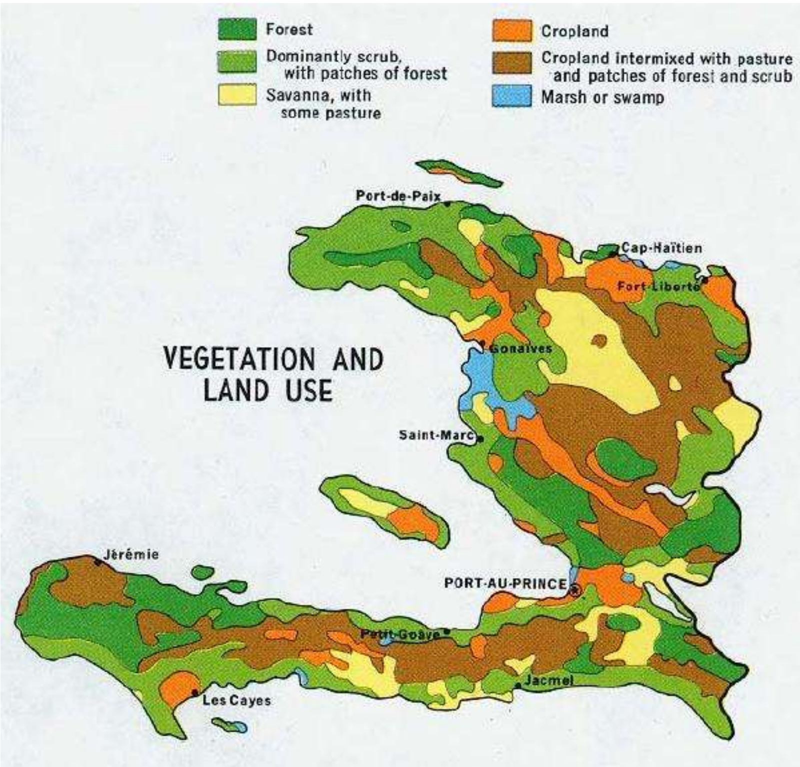


Image 3-32. Example of land use map.

2. Evaluation of the land

In this case, the user has to bear in mind the patrimonial value of the soil, whether it is non-development land, building land or urban land, of each group according to its category.

The total sum of the evaluation of the production of the land and the patrimonial value allow obtaining the expropriation value.

Image 3-33. Dry land vs. Irrigated land.

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES (TADIL)

CHAPTER 4. TYPE SECTIONS

GUÍA METODOLÓGICA DE APLICACIÓN

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES

Methodological Application Guide

CHAPTER 4. TYPE SECTIONS.
EDITION 1.

This chapter describes the different type sections that can be implemented for roads.

The definition of the type section includes the elements that define the geometry of the surface of the infrastructure, which are basically widths and transverse slopes, as well as the type of longitudinal hard shoulder. The user can choose between Simple and Double Sections, and, in the Double Section, between dual carriageway, controlled-access motorway and motorway section without a central reservation. The sections are defined in order to enable the development of Informative Studies, so there are limitations in the definition of certain elements of the section. Regarding the evaluation of alternatives and the analysis, the definition of the cross-section is sufficient for an Informative Study.

TYPE SECTIONS

SUB-CHAPTER 0. PROCEDURE.

0. Introduction

This chapter describes the process of defining the different solutions of the type section that are produced for creating Informative Studies.

1. Methodology

The methodology follows this process:

a. Definition of ditches: There are menus for both triangular and trapezoidal ditches.

b. Definition of type sections including the previously defined ditches.

The program allows saving the ditches with a name and later inserting them in the cross section by selecting it.

When the user does not create a ditch, the program creates the cross sections without ditches.

Finally, it is worth pointing out that other elements such as walls or berms are inserted in the lateral slope of the cut section from the ditch.

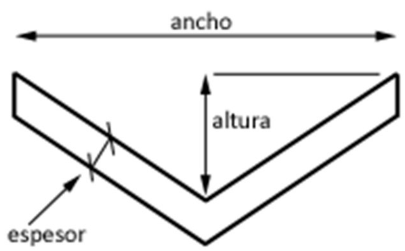
SUB-CHAPTER 1. DEFINITION OF DITCHES

0. Types of ditches included in the TADIL software

The program allows inserting triangular ditches and trapezoidal ditches. For defining them, there are two menus, where the user must input the geometrical information, the name and the description. The assignment of materials and budget items is performed in each Type Section Menu and not in the Ditches Menu. The reason lies in the possibility of defining ditches of the same geometry but of different materials and, consequently, of different prices.

1. Triangular ditches

The triangular ditch is defined by the wideness at the top, the deepness in the centre and the thickness of the material. The menu allows describing the ditch and assigning it a name. Naming it allows the subsequent identification and importation of the ditch into the sections.



c

2. Trapezoidal ditches

The trapezoidal ditch is defined by the wideness at the top, the wideness at the bottom, the height and the thickness of the material. As in the previous case, the menu allows describing the ditch and assigning it a name so that it can later be imported into the sections.

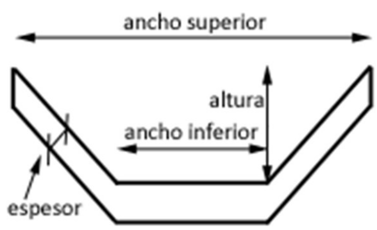


Image 4-2. Geometry of trapezoidal ditch.

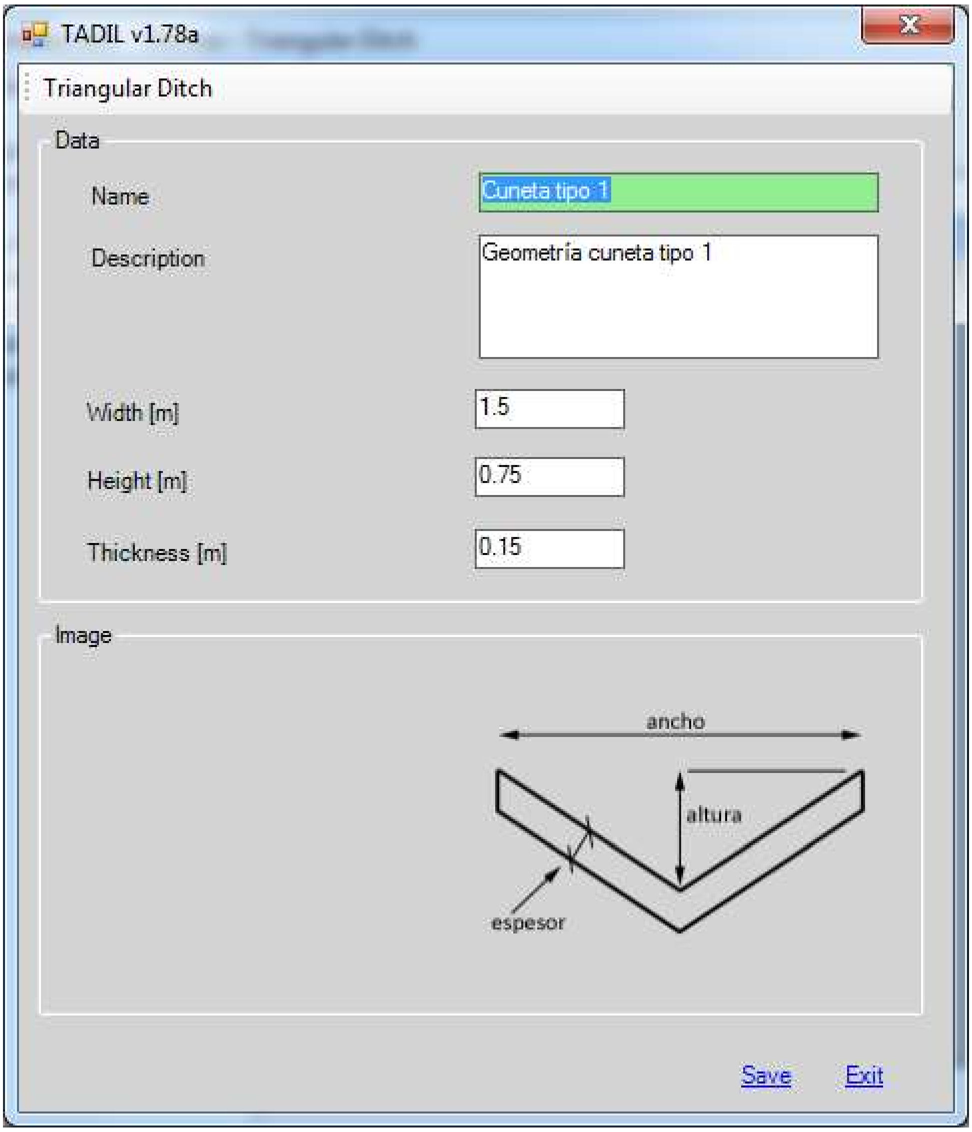


Image 4-3. Menus of triangular and trapezoidal ditches.

TYPE SECTIONS

SUB-CHAPTER 2. DEFINITION OF THE TYPE SECTION.

0. Types of type sections

The menus included allow defining the following types of roads:

- Simple Section.
- Double Section.
- – With a central reservation.
- – Without a central reservation.

1. Definition of Simple Section

The information that defines the Simple Section is as follows:

- Name of the section and description.
- Type of ditch (triangular or trapezoidal).
- Material of the ditch (construction unit assigned for the budget).
- Position (on the sidewalk or on the berm). If on the sidewalk, it indicates that the ditch is located on the lower level of the sidewalk at the level of the esplanade. If on the berm, this means that the ditch starts on the edge of the berm.
- Geometry of the section:
  - Width of the lane (in metres).
  - Number of lanes on the left side (unities).
  - Number of lanes on the right side (unities).
  - Width of the hard shoulder (in metres).
  - Width of the berm (in metres).
  - Slope of the berm on peak.
  - Slope of the sidewalk (regarding the horizontal line); to simplify, the program assigns this slope to all the inner layers of the sidewalk in the carriageway and the hard shoulder, as well as the outer slope of the berm.
  - Extension of the carriageway pavement into the hard shoulder.

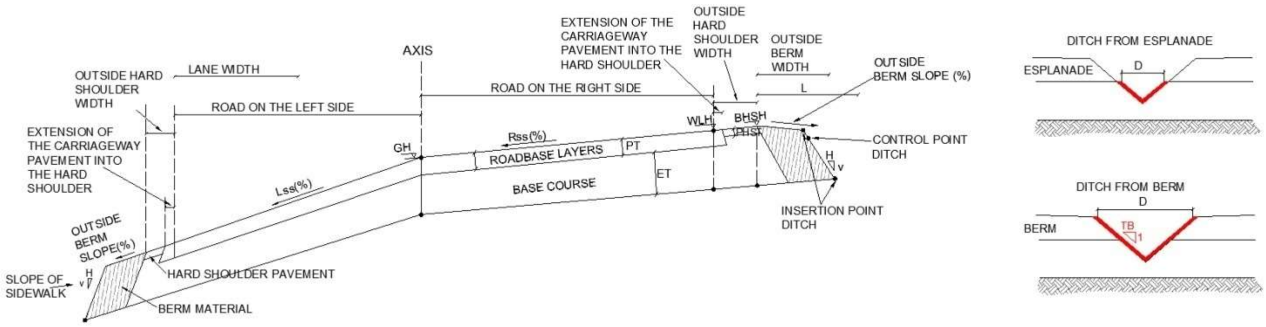


Image 4-4. Simple Section (scaled transversal banking).

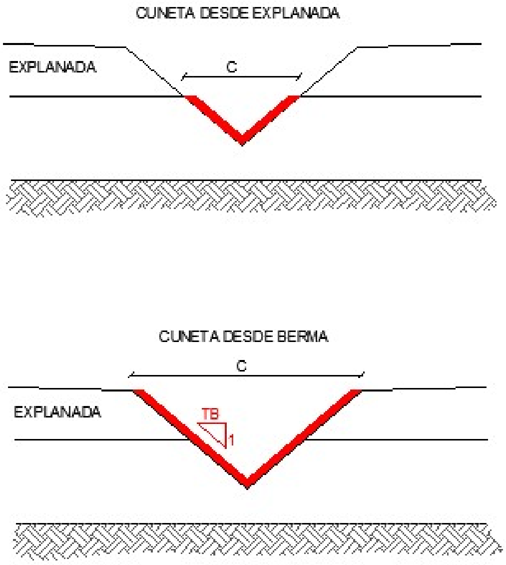


Image 4-5. Possible locations of ditch

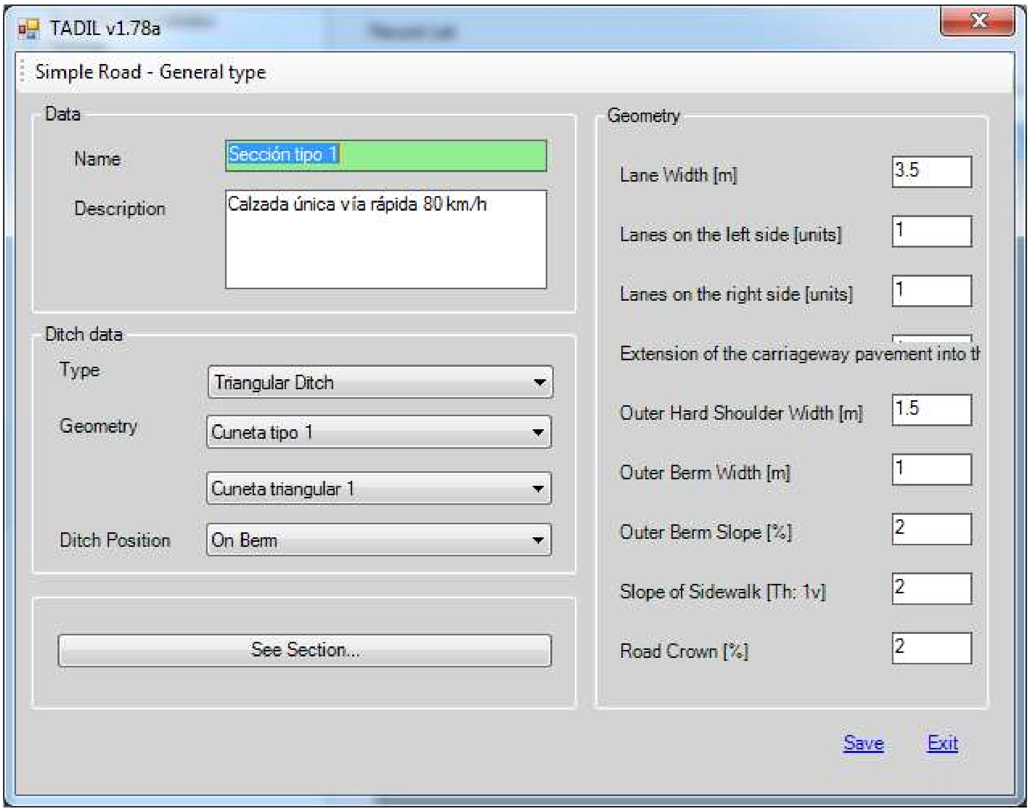


Image 4-6. Menu for inserting information in the Simple Section.

2. Definition of Double Section

2.1. Dual carriageway or controlled-access motorway section

For defining the Double Section of dual carriageways or controlled-access motorways, further information is required, as follows:

- It includes the definition of the inner ditch, as well as that of the outer ditch, by defining the type, the geometry and the construction unit that is assigned. In the cross section, the ditch is inserted at the end of the inner berm.

- The additional information of the geometry of the dual carriageway section with regard to the Simple Section is:

- The width of the central reservation (in metres), including the ditch and the inner berms at each side of the ditch of the central reservation.
- The width of the inner hard shoulder (in metres).

The axis matches the axis of the ditch, and the gradient matches the intersection of the hard shoulder and the central reservation. This aspect is very important when defining the connections of the axis of the road at the start and end points of the route. The geometry of the section is defined in the following image:

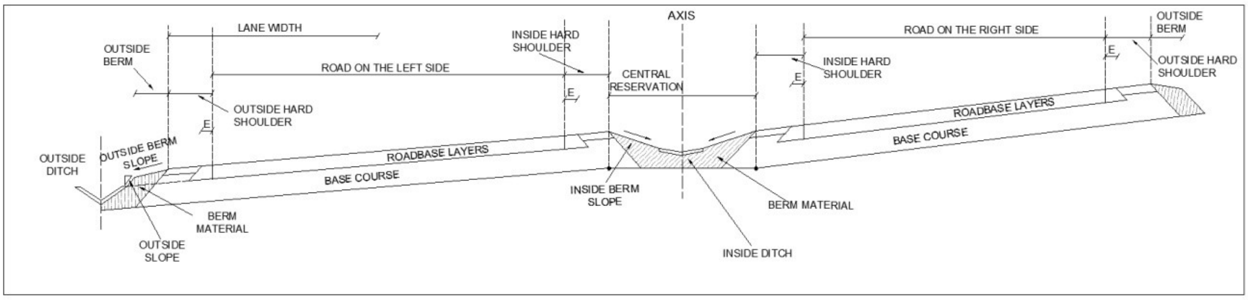


Image 4-7. Double Section for dual carriageways or controlled-access motorways.

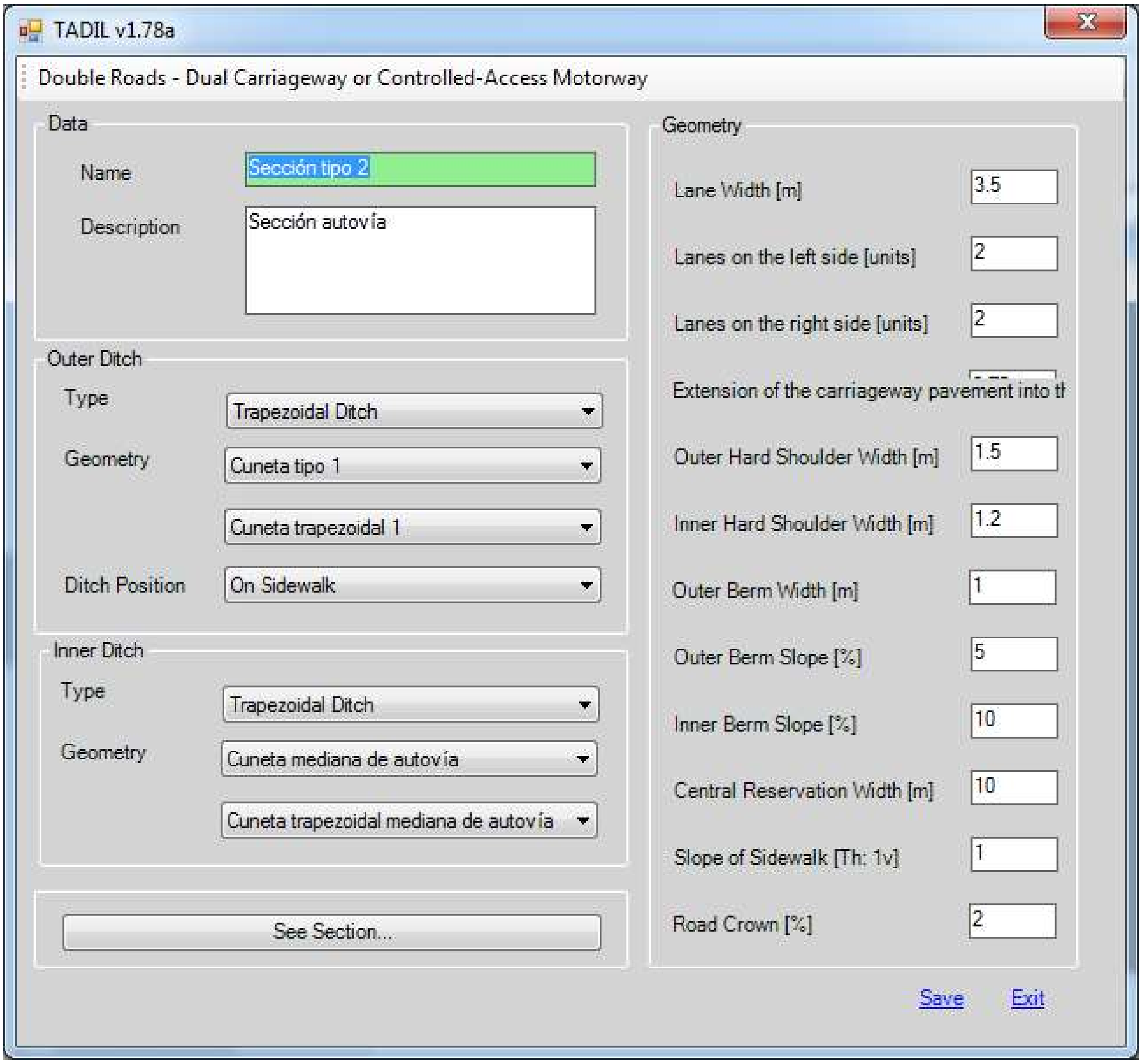


Image 4-8. Menu for inserting information on the Double Section for dual carriageways or controlled-access motorways.

2.2. DOUBLE SECTION WITHOUT A CENTRAL RESERVATION

The Double Section is formed like the previous one with the exception that there is no central reservation, and so therefore there is also no intermediate ditch. In the middle of the section, coinciding with the axis, is a barrier that the user can select in .dwg format. The program by default suggests a graphic object.

In the Double Section, the axis corresponds to the point where the inner hard shoulders join, and the height of the gradient is defined with respect to that point.

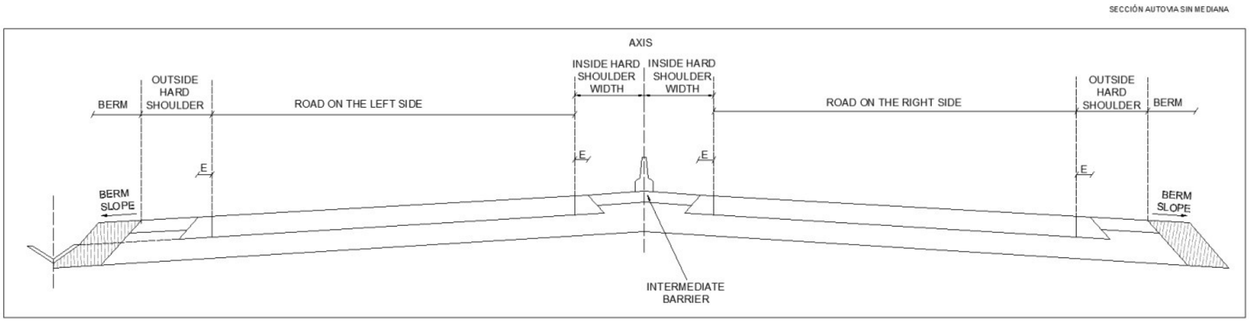


Image 4-9. Double Section for motorway without a central reservation.

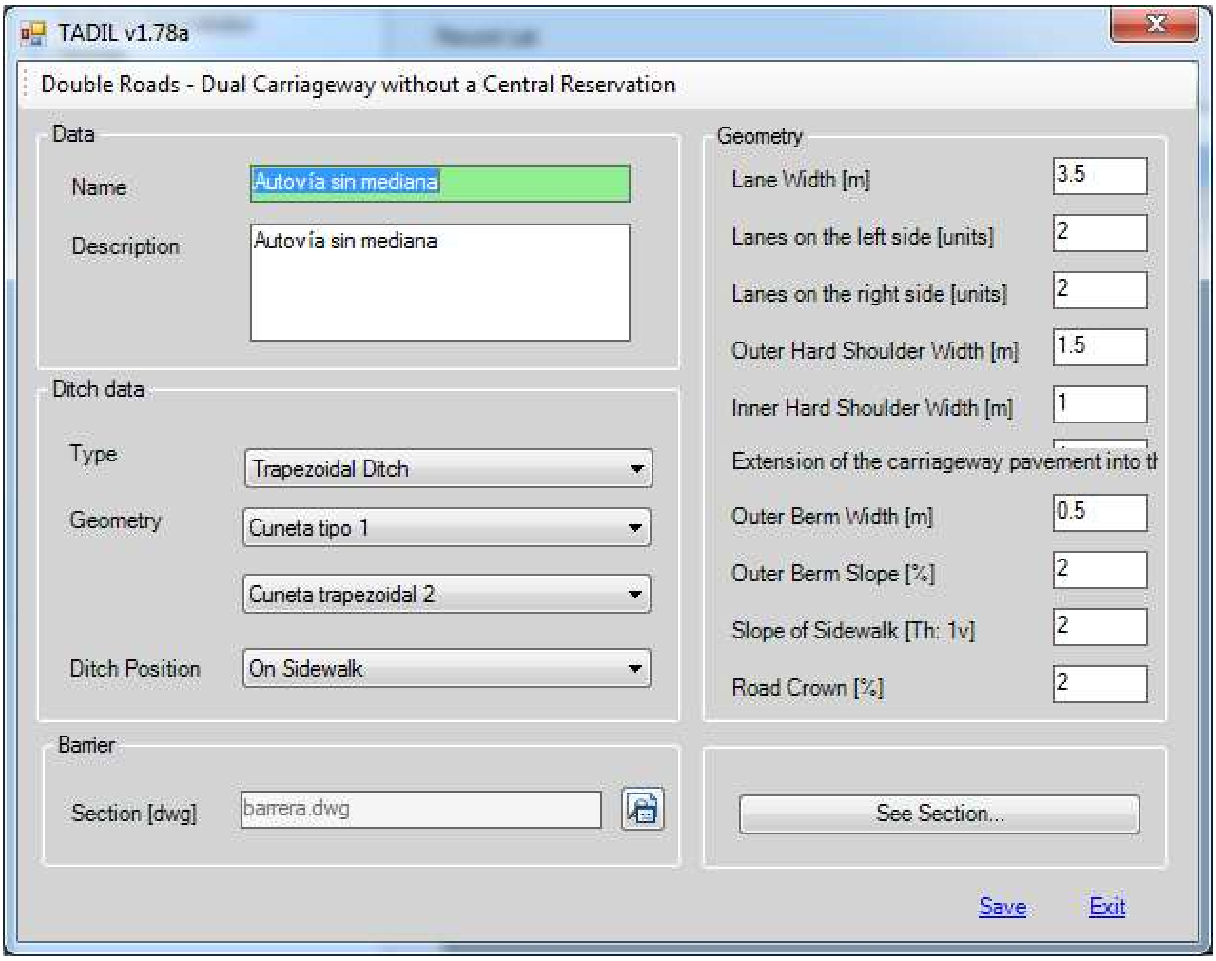


Image 4-10. Menu for inserting information on the Double Section without a central reservation.

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES (TADIL)

CHAPTER 5. BUDGET AND PROFITABILITY

ECONOMIC INTEREST GROUP TADIL PROJECT

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES

Methodological Application Guide

CHAPTER 5. BUDGET AND PROFITABILITY

EDITION 1.

This chapter may possibly be the most interesting one for the users who represent a public administration or an infrastructure development company.

This application tries to answer questions such as if the construction of an infrastructure is profitable and the investment that is needed. Both of these enquiries can be made regarding public and private investment. Both if the investment is performed by a public administration or by a private company, the social or general profitability has to be analysed, to see if the construction is beneficial for the end users and for the administration that represents them. Therefore, although a controlled-access motorway, for instance, demands the payment of a toll and/or state subsidies, it may be advantageous as long as it implies a reduction in operation costs or travel time (measured in economic terms), a reduction in conservation and maintenance costs for the administration, etc.

Similarly, the software is configured for the analysis of purely private investments or public-private collaboration investments with the possibility that the development company covers part or the totality of the investment.

CHAPTER 5. BUDGET AND PROFITABILITY

SUB-CHAPTER 0. PROCEDURE.

0. Introduction

This chapter describes the procedure for configuring the budget and the economic feasibility study that is carried out afterwards.

1. Methodology

When the user reaches this phase of the project, the software will have generated all the measurements of the construction work. Now the user has to assign construction units as macro-prices.

To do so, the program includes the option of configuring and saving groups of macro-prices that can be combined depending on the type of construction work. The macro-prices use the construction units inputted in the Construction Units Menu for the following budget chapters:

- Longitudinal and transversal drainage.
- Signalling, beacons and traffic barriers.
- Replacement of services.
- Geotechnical corrections.
- Provisional diversions.
- Complementary actions.
- Corrective measures.
- Workplace health and safety.

This creates a combination of macro-prices for the abovementioned construction units that can be used in any project.

In order to save the combination of macro-prices, TADIL suggests four large groups that correspond to the groups of type sections.

- Simple Section.
- Double Section dual carriageway or controlled-access motorway.
- Double Section dual carriageway or controlled-access motorway without a central reservation.

Once the macro-prices are defined, the program can render the material execution budget of the project.

In order to generate the Base Project Bid Estimate and the Budget Report for the Administration, the user must input the percentages that correspond to the following:

- Base Project Bid Estimate:
    - General expenditures
    - Industrial profit
    - Quality control

- VAT

- Budget Report for the Administration:

  - Patrimony conservation costs
  - Additional quality control costs
  - Landscape restoration
  - Other
  - Areas of rights of way (width in metres): this will allow calculating the cost of the expropriations

The user has to consider which percentages to use according to the current regulations as well as their corresponding values.

With the abovementioned values the user will be able to calculate the budget and therefore start calculating the profitability. It must be indicated whether the promoter is public or private, as well as the traffic and economic management information that define the investment. The parameters that the TADIL software uses in its economic analysis are the correlation between benefits and costs and the Net Present Value.

1. List of macro-prices

As mentioned earlier, the user can create combinations of macro-prices in compliance with the type of infrastructure that is going to be designed, and classify them according to the sort of type section.

The combinations of macro-prices are carried out according to the following concepts:

- Longitudinal and transverse drainage
- Signalling, beacons and traffic barriers
- Replacement of services
- Geotechnical corrections
- Provisional diversions
- Complementary actions
- Corrective measures
- Workplace health and safety

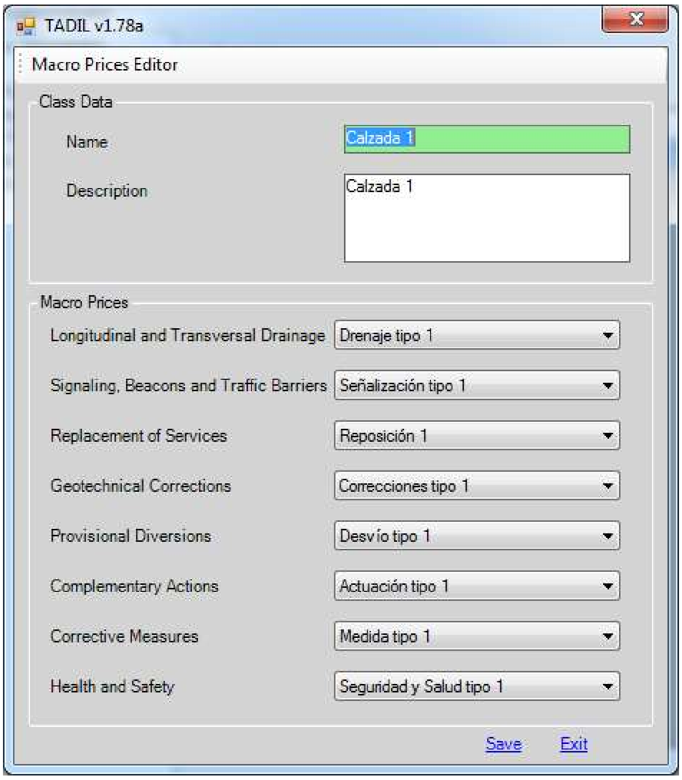


Image 5-1. Menu of groups of macro-prices.

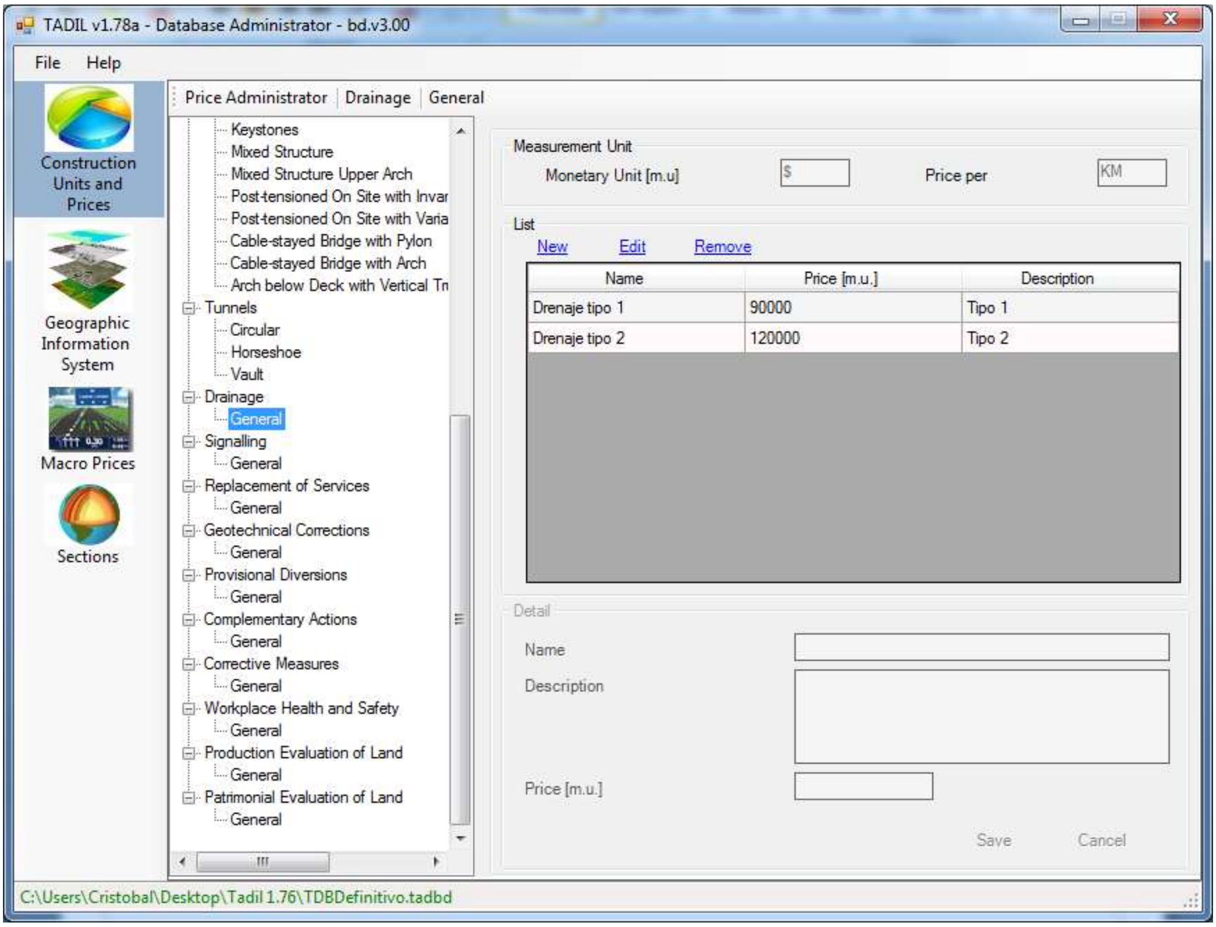


Image 5-2. The input of macro-prices.

The user can select the required combination of macro-prices according to the type of construction work being designed.

2. Base Project Bid

Once the macro-prices are inserted and the measurements of the construction work are calculated, TADIL automatically obtains the Real Execution Budget (REB). To obtain the Base Project Bid (BPB) the user must input the following information as a percentage relative to the REB:

- General expenditures
- Industrial profits
- Quality control
- VAT

The abovementioned values are applied to all the alternatives defined by the user that are going to be compared.

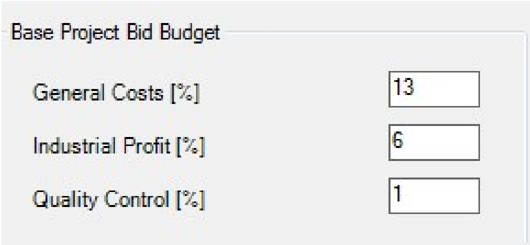


Image 5-3. Menu for the input of information for obtaining the BPB.

3. Budget Report for Administration

Similarly, the user inputs the following information to obtain the Budget Report for Administration (BRA):

- Conservation of the patrimony (as a percentage relative to the BEM)
- Quality control (as a percentage relative to the BEM)
- Landscape restoration (as a percentage relative to the BEM)
- Other, such as compensatory or corrective measures (as a percentage relative to the BEM)
- Easement area (width in metres); this allows calculating the cost of expropriations by using the following values inserted in the GIS menu: the production costs in socio-economic variables, and the value of the land in patrimonial variables.

Image 5-4. Menu for the input of information for obtaining the BRA

1. Profitability Study

1.1. Procedure

The procedure to determine the profitability of the construction of the infrastructure implies finding out the cost balance between option 0 (maintaining the old connection) and the construction of the chosen alternative, and follows this sequence:

- Determining the cost of accidents
- Determining the operation costs
- Determining the cost of time
- Weighting costs in accordance with the percentage of heavy vehicles and the current and future distribution of the traffic.
- Determining the exploitation costs, road maintenance costs, insurances, tolls and state subsidies.
- Study of social and/or private profitability according to the cost balance between the current situation (option 0) and each of the alternatives.

It is worth indicating that for the development of the Profitability Study, there has to be a forecast of the evolution of traffic that determines the increase and distribution of traffic on the new infrastructure and on the old connection, in case it is maintained.

The following sections describe the menus and the operations for calculating the costs and profitability according to the abovementioned steps.

1.2. Cost of accidents

Regarding the costs derived from accidents, a quantitative model is used, where each alternative considers the costs regarding the accidents that are expected to take place according to regional statistics or to the type of road. The road users take responsibility for these accidents either directly or through a subsidiary insurance, with mandatory and private insurances policies. The comparison should be carried out regarding the real costs that are produced in the old connection, which can be obtained in official reports or estimated in relation to the average values.

The analysis of costs and benefits is calculated with the following formula:

$$CPA = ND \cdot CD + NI \cdot CI$$

Where:

CPA = cost per accident in the complete section during a year.

ND = number of deaths in the section during a year.

NI = number of injured in the section during a year.

CD = average unitary cost per death.

CI = average unitary cost per injured.

A statistical method is used for determining the number of accidents. The number of accidents per year and alternative are those that have taken place during the base year, that is, the last year with statistical data, increased according to the evolution of the traffic. This hypothesis implies that the danger and mortality indexes do not vary during the whole period of analysis.

In the statistical method, the number of deaths and injured is determined with the following formulas:

$ND = 365 . ADT . L . MI . 10^{-8}$

$NI = K . 365 . ADT . L . DI . 10^{-8}$

Where:

ND = number of deaths in the section during a year.

NI = number of injured in the section during a year.

ADT = average daily traffic of the section.

L = Length of the section.

MI = mortality index.

DI = danger index.

K = average number of injured per accident.

The DI and MI of roads are published. When this information is not published, the average values published per district, state or region can be used.

Lastly, the unitary cost assigned per accident is calculated taking into account the current insurance market and the values of the insurance policies in the case of death or injury. In Spain, the values that are frequently used are as follows:

Death = 150,000 €.

Injury = 42,000 €.

Therefore:

Cost of accident: NI x CI + ND x CD = NI x 42,000 + ND x 150,000

When determining the cost balance of accidents between option 0 and the corresponding alternative, the user must consider whether or not to maintain the old connection. If the old connection is to be maintained, the accident costs of the traffic that remains on the old connection have to be added to the accident costs of the new connection.

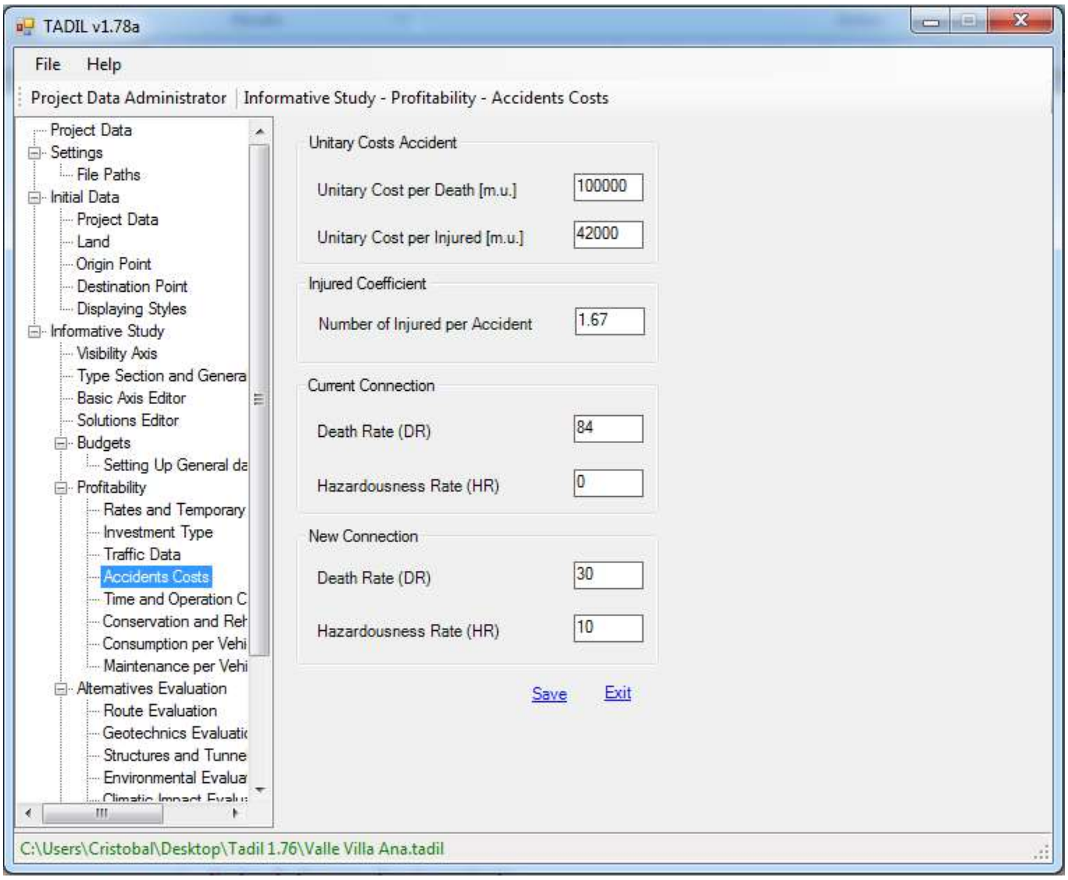


Image 5-5. Menu for the input of information for calculating accident costs.

1.3. Operation costs

The operation costs include the following variables:

- Vehicle pay-off
- Fuel.
- Lubricants
- Maintenance of the vehicle
- Tyres

These costs can be defined according to more or less complex formulas. TADIL uses some of the most common formulas in the field of the car industry. All of this information can be edited by the user.

Next, each of the variables that define the operation costs is described.

- Pay-off, conventional information per kilometre

The vehicle pay-off is the relationship between the price of purchase and the number of kilometres of service life of the vehicle. In Spain, the common values are as follows:

Light vehicle: 0.03 €/km

Heavy vehicle: 0.05 €/km

- **Maintenance costs of the vehicle**

The maintenance of the vehicle depends on the speed chosen by the user for each section.

The following are maintenance costs:

- Brakes.
- Tune-up.
- Small repairs.

Regarding light vehicles, TADIL suggests the following traditional formula:

$$CPK = 0.1034 \cdot S^{-0.44} \ (€/km)$$

where CPK is the cost per kilometre and S is the speed of the distance in km/h.

Regarding heavy vehicles, the cost is:

$$CPK = 0.4034 \cdot S^{-0.44} \ (€/km)$$

where CPK is the cost per kilometre and S is the speed of the distance in km/h.

- **Fuel costs**

The cost of fuel also depends on the speed.

These are the common values for heavy vehicles:

Speed (km/h)	Fuel consumption
	Consumption c.c./km
20	700.0000
30	675.0000
40	660.0000
50	680.0000
60	725.0000
70	750.0000
80	800.0000
90	850.0000
100	900.0000

Table 5-1. Example of fuel consumption data forheavy vehicles.

For light vehicles:

	Fuel consumption

Speed (km/h)	Consumption c.c./km

20	166.5000
30	146.3500
40	132.3200
50	127.1000
60	124.5700
70	129.2000
80	140.4000
90	154.5100
100	178.3200

Table 5-2. Example of fuel consumption data for light vehicles.

The user can edit the previous information according to his or her experience and knowledge.

The price of the fuel is different in each country and experiences large fluctuations throughout the year.

- Cost of lubricants

The cost of lubricants also depends on the speed of the vehicle.

The formulas that TADIL suggests are as follows:

A) CARS

$CPK = 0{,}012 \cdot C \cdot PO$

Where:

CPK = Cost of engine oil per kilometre for cars

C = Petrol consumption in litres

PO = Price of the engine oil

B) TRUCKS

$CPK = 0{,}008 \cdot C \cdot PO$

Where:

CPK = Cost of engine oil per kilometre for trucks

C = Diesel fuel consumption in litres

PO = Price of the engine oil

Both in the case of fuels and in the case of lubricants the user should consider the costs without taxes, because in the study of social profitability these taxes revert to the state, which also benefits from the construction of the infrastructure, together with the users.

- Tyres

It is considered that:

Cars: 0.00875 €/km.

Trucks: 0.06 €/km.

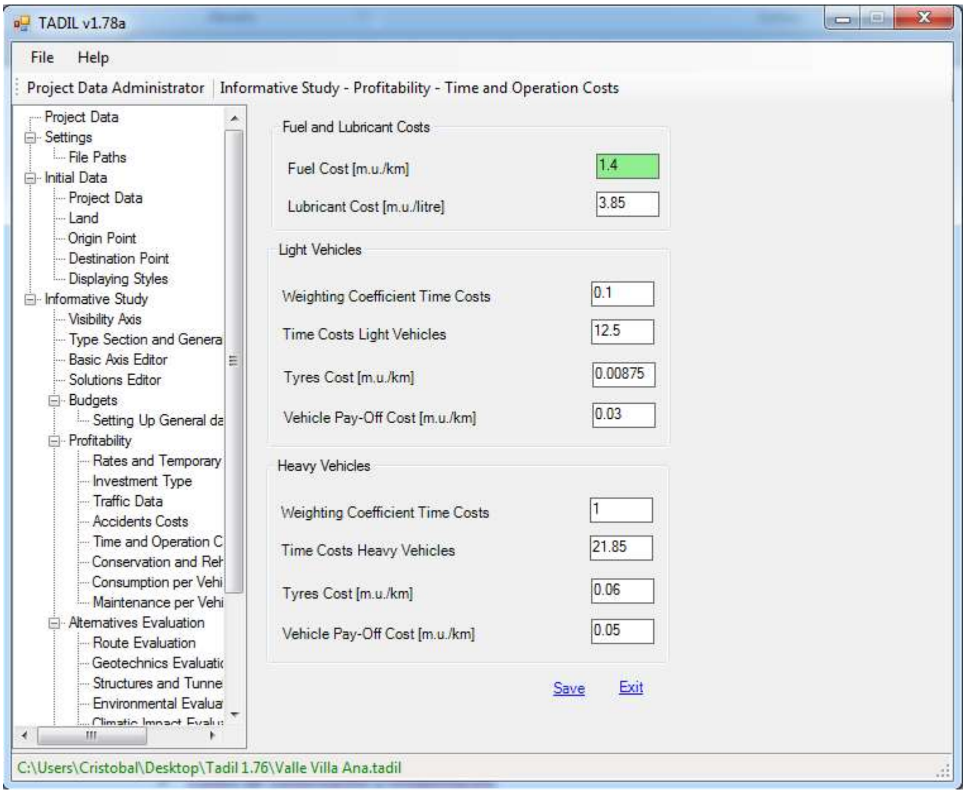


Image 5-6. Menu for the input of information of operation and time costs.

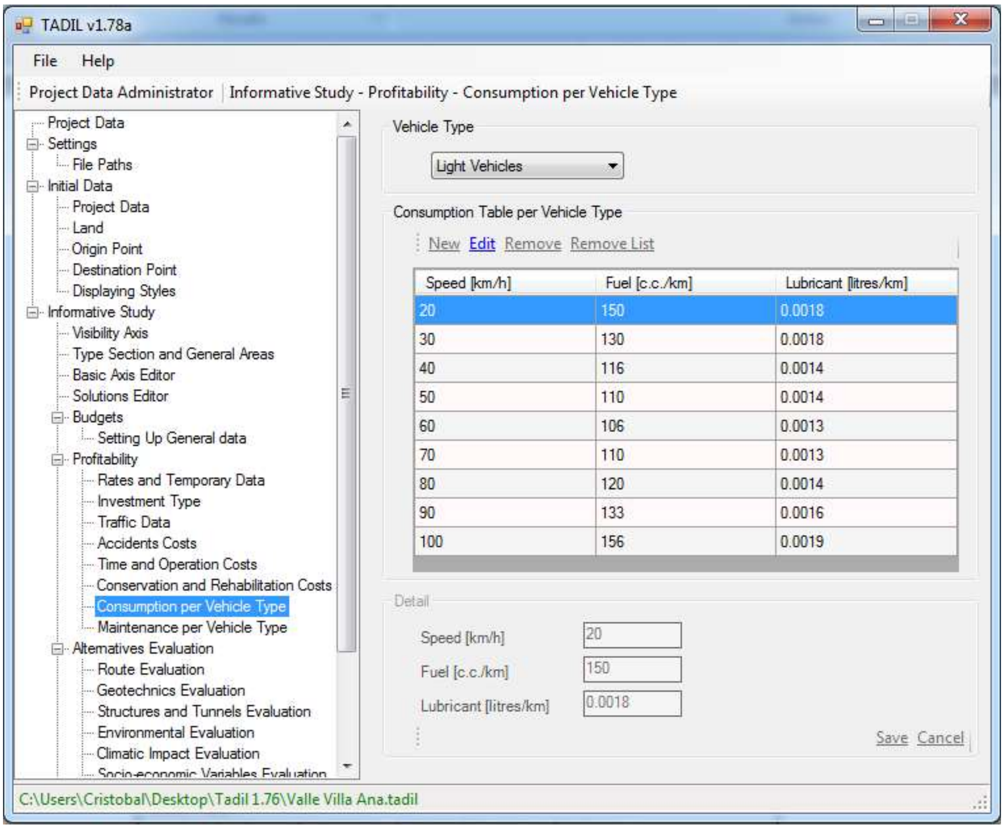


Image 5-7. Menu for the configuration of tables of operation costs for light vehicles.

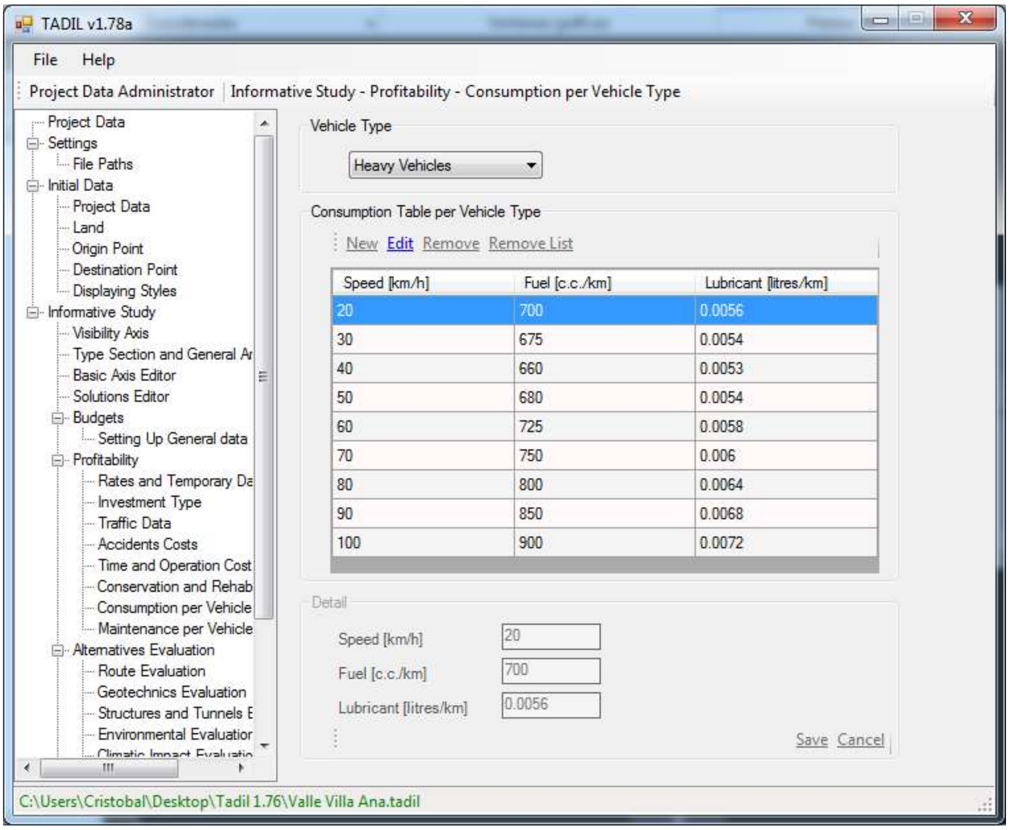


Image 5-8. Menu for the configuration of tables of operation costs for heavy vehicles.

1.4. Time costs

The reduction of travel time is the most relevant aspect of all the benefits derived from a new route, sometimes reaching between 70 and 80 % of these benefits.

The cost of each alternative is expressed as follows:

CPT = T·P,

Where:

CPT = Cost of travel time of the section.

T = Travel time of the section, in hours.

P = Value of the time, in €/h.

The time spent in a given distance is obtained from the following:

T = L/S,

Where:

T = Travel time of the section, in hours.

L = Length of the section, in km.

S = average speed of the vehicle, in km/h

Traditionally in Spain, the values have been as follows:

Light vehicle: 12.75 €/h.

Heavy vehicle: 21.85 €/h.

Currently, however, they are outdated. The user can indicate the estimated value according to his or her knowledge and experience of the market surrounding each infrastructure.

Also, TADIL incorporates a weighting coefficient for the cost of light vehicles. If we consider it a 0, a quantifiable benefit for saving time is not attributable to light vehicles, only to heavy vehicles, because we know for certain that a professional task is being carried out (in this case, transport). This coefficient, with values from 0 to 1, considers that only a small part of the users of light vehicles carries out a professional task. Therefore, a driver that uses the infrastructure on weekends to travel to the beach in his or her spare time is not the same as a salesperson or representative that travels to his or her workplace, with a value assigned per hour of salary or productivity. Traditionally most of the profitability studies have been considering this coefficient as value 1, thus entailing that most of the users "would be willing to pay" for reducing their travel time, at least up to a value of T·P.

With this coefficient for light vehicles, the cost of travel time is expressed as follows:

CPT = T·P·R,

Where:

CPT = Cost of travel time of the section.

T = Travel time of the section, in hours.

P = Value of the time, in €/h.

R = Weighting of costs of light vehicles.

1.5. Weighting of costs

This consists in obtaining the average value per kilometre of the operation and time costs considering the distribution of heavy and light vehicles.

When we know the costs of transport and the percentage of heavy vehicles on the road, the weighting of costs is as follows:

$$C = CLV \cdot PLV + CHV \cdot PHV,$$

Where:

CLV: costs of light vehicles.

PLV: percentage of light vehicles, in so much per one.

CHV: costs of heavy vehicles.

PHV: percentage of heavy vehicles, in so much per one.

Here is an example of calculation:

Weighting of costs of light and heavy vehicules

Weighting of costs of time, light vehicules	0.5	
Costs of time, light vechicles	12.75	€/h
Costs of time, heavy vechicles	21.85	€/h
Cost of fuel	0.75	€/l
Cost of engine oil	3.84	€/l
Percentage of heavy vehicles	3	%

LIGHT VEHICLES

Speed (km/h)	Fuel consumption		Engine oil consumption		Cost of tyres and pay-off	Maintenance costs	Total costs	Time costs	Total costs with time
	Consump. c.c./km	Consump. €/km	Consump. c.c./km	Consump. €/km	Consump. €/km	Consump. €/km	€/km	€/km	€/km
20	150,0000	0,1125	0,0018	0,00691	0,0388	0,0277	0,1858	0,3188	0,5046
30	130,0000	0,0975	0,0016	0,00599	0,0388	0,0232	0,1654	0,2125	0,3779
40	116,0000	0,0870	0,0014	0,00535	0,0388	0,0204	0,1515	0,1594	0,3109
50	110,0000	0,0825	0,0013	0,00507	0,0388	0,0185	0,1448	0,1275	0,2723
60	106,0000	0,0795	0,0013	0,00488	0,0388	0,0171	0,1402	0,1063	0,2465
70	110,0000	0,0825	0,0013	0,00507	0,0388	0,0159	0,1423	0,0911	0,2333
80	120,0000	0,0900	0,0014	0,00553	0,0388	0,0150	0,1493	0,0797	0,2290
90	133,0000	0,0998	0,0016	0,00613	0,0388	0,0143	0,1589	0,0708	0,2297
100	156,0000	0,1170	0,0019	0,00719	0,0388	0,0136	0,1766	0,0638	0,2403

HEAVY VEHICLES

Speed (km/h)	Fuel consumption		Engine oil consumption		Cost of tyres and pay-off	Maintenance costs	Total costs	Time costs	Total costs with time
	Consump. c.c./km	Consump. €/km	Consump. c.c./km	Consump. €/km	Consump. €/km	Consump. €/km	€/km	€/km	€/km
20	700,0000	0,5250	0,0056	0,02150	0,1100	0,1080	0,7645	1,0925	1,8570
30	675,0000	0,5063	0,0054	0,02074	0,1100	0,0903	0,7273	0,7283	1,4556
40	660,0000	0,4950	0,0053	0,02028	0,1100	0,0796	0,7049	0,5463	1,2511
50	680,0000	0,5100	0,0054	0,02089	0,1100	0,0721	0,7130	0,4370	1,1500
60	725,0000	0,5438	0,0058	0,02227	0,1100	0,0666	0,7426	0,3642	1,1068
70	750,0000	0,5625	0,0060	0,02304	0,1100	0,0622	0,7578	0,3121	1,0699
80	800,0000	0,6000	0,0064	0,02458	0,1100	0,0587	0,7932	0,2731	1,0664
90	850,0000	0,6375	0,0068	0,02611	0,1100	0,0557	0,8293	0,2428	1,0721
100	900,0000	0,6750	0,0072	0,02765	0,1100	0,0532	0,8658	0,2185	1,0843

WEIGHTING

Speed (km/h)	Fuel consumption		Engine oil consumption		Cost of tyres and pay-off	Maintenance costs	Total costs	Time costs	Total costs with time
	Consump. c.c./km	Consump. €/km	Consump. c.c./km	Consump. €/km	Consump. €/km	Consump. €/km	€/km	€/km	€/km
20	166,5000	0,1249	0,0019	0,00735	0,0409	0,0301	0,2032	0,3420	0,5452
30	146,3500	0,1098	0,0017	0,00643	0,0409	0,0252	0,1822	0,2280	0,4102
40	132,3200	0,0992	0,0015	0,00579	0,0409	0,0222	0,1681	0,1710	0,3391
50	127,1000	0,0953	0,0014	0,00554	0,0409	0,0201	0,1619	0,1368	0,2986
60	124,5700	0,0934	0,0014	0,00541	0,0409	0,0186	0,1583	0,1140	0,2723
70	129,2000	0,0969	0,0015	0,00561	0,0409	0,0173	0,1607	0,0977	0,2584
80	140,4000	0,1053	0,0016	0,00610	0,0409	0,0163	0,1686	0,0855	0,2541
90	154,5100	0,1159	0,0018	0,00673	0,0409	0,0155	0,1790	0,0760	0,2550
100	178,3200	0,1337	0,0020	0,00780	0,0409	0,0148	0,1972	0,0684	0,2656

Table 5-3. Example of weighting of costs of light and heavy vehicles.

1.5. EXPLOITATION COSTS, ROAD MAINTENANCE COSTS, INSURANCES, TOLLS AND STATE SUBSIDIES.

- Road maintenance costs

When evaluating the road maintenance and conservation costs, we take into account the most common values in road maintenance agreements of administrations with private companies. These values depend on the type of infrastructure, the country and the given administration. As an example, in Spain the following values for autonomic roads are currently considered:

- Conservation and maintenance costs: 1,800.00 €/km per year.

- Rehabilitation costs: 12,000.00 €/km every 10 years.

The conservation costs are charged every year, and the rehabilitation costs are charged every 10 years.

TADIL considers that when the pre-existing infrastructure is also maintained, during the first year of exploitation of a new infrastructure the old one will be rehabilitated, because most of the traffic is diverted to the new connection. Therefore, during the first year of exploitation, the administration covers the rehabilitation of the old road. The following nine years, the old connection is maintained and conserved, and on the tenth year, it will again be rehabilitated. This ten-year cycle is repeated over again.

Considering that the investment of the new infrastructure can be public or private, and that the pre-existing connection can either be eliminated or maintained, there are different possibilities:

- That the promotion of the new infrastructure is private and the old connection is maintained:

In this case, the public administration does not have to maintain the new infrastructure or rehabilitate it, but it will have to maintain the old one, which will be rehabilitated during the first year of exploitation of the new connection.

- That the promotion of the new infrastructure is private and the old connection is not maintained:

In this case, the administration will not have to consider any rehabilitation or maintenance costs.

- That the promotion of the new infrastructure is public and the old connection is maintained:

In this case, the administration will cover the conservation and maintenance costs of the old and the new roads. However, *it is important to remember that during the first year of exploitation the old road will have rehabilitation costs and the new road will have maintenance costs*. There will be ten-year cycles in both cases.

- That the promotion of the new infrastructure is public and the old connection is not maintained:

In this case, the administration will only cover the conservation and maintenance of the new road. During the first year, there will only be maintenance costs.

Regarding partially private or completely private investments, TADIL always considers that the exploitation costs of the new infrastructure are covered by the private promoter.

These aspects are essential for obtaining the annual balance sheet of the exploitation and, therefore, for obtaining the profitability ratios.

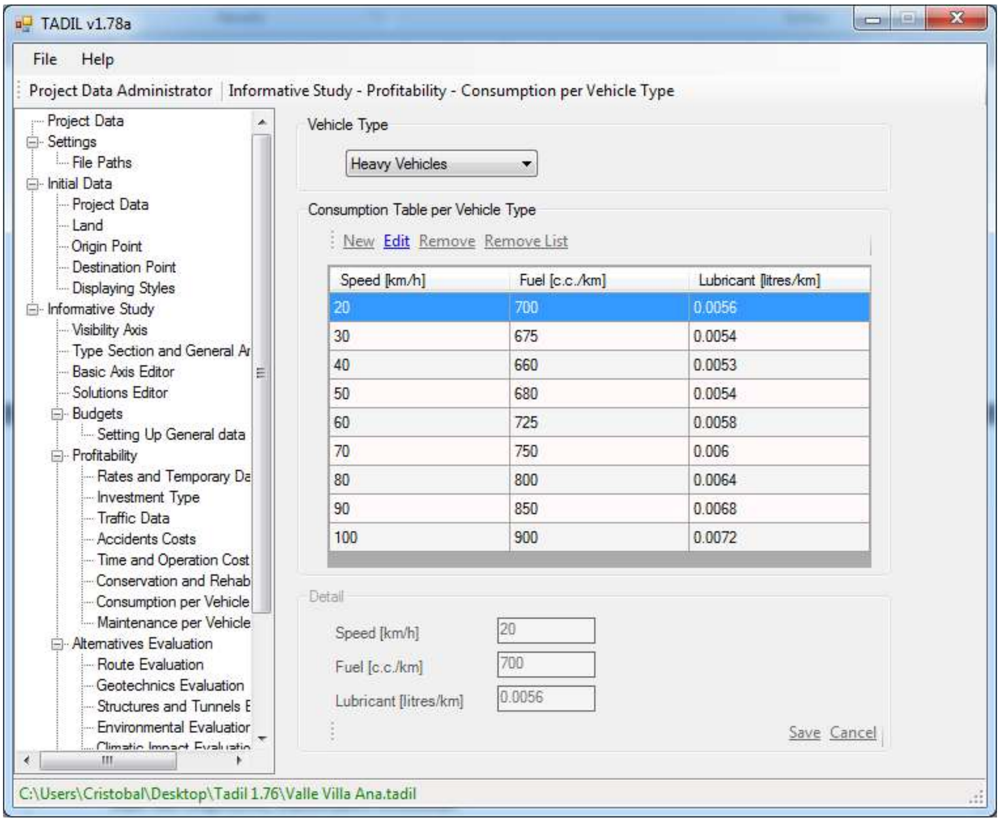


Image 5-9. Menu for the input of the maintenance and rehabilitation costs.

- Exploitation costs

If a private concession of the exploitation is granted, for the economic study of the business profitability of the investment, the costs derived from the exploitation must be considered. These costs are derived from the following organization chart:

<u>Management and administration of the concession:</u>

Staff: manager, administratives and accounting manager.

Costs: offices, vehicles, maintenance and cleaning.

<u>Access control and payments:</u>

Staff: toll employees, maintenance technician.

Costs: maintenance and cleaning of toll facilities; rental of warehouse.

The following is a real example of exploitation costs per year considered in a profitability study developed in 1997 in euros:

Toll employees: 50 x 11,000 € = 550,000 € / year

Manager: 42,000 € / year.

Accounting manager: 25,000 € / year.

Administratives: 2 x 12,000 € = 24,000 € / year.

Office: 7,000 € / year.

Vehicles: 20,000 x 2 / 10 = 4,000 € /year

Cleaning: 6,000 € / year.

Maintenance technician: 30,000 € / year.

Warehouse: 7,000 € / year.

General expenditures: 25,000 € / year.

TOTAL: 720.000 € / year.

Number of direct jobs created: 55.

- Insurances

In profitability studies for private management, there is also the possibility of considering the costs related with hiring a general insurance that covers the accidents of road users, in such a way that the payment of the toll includes the corresponding life and/or disability insurance, irrespective of the private insurance hired by the user. This option is not common in the management of tolls of many countries, although they are carried out in some countries of the European Union, involving an improvement of the services for the road use.

The costs derived from this insurance are covered by the private promoter.

- Tolls

The tolls imply a cost in the analysis of social profitability, but an income in the analysis of private profitability. The total cost is obtained by multiplying the total number of vehicles by the toll fare.

- State subsidies

For public-private options, the payment is usually done per year, according to a value agreed in a contract or updated according to the Consumer Price Index. This value represents the annual income of the licensed company.

Moreover, in this case, there may or may not be a toll per vehicle.

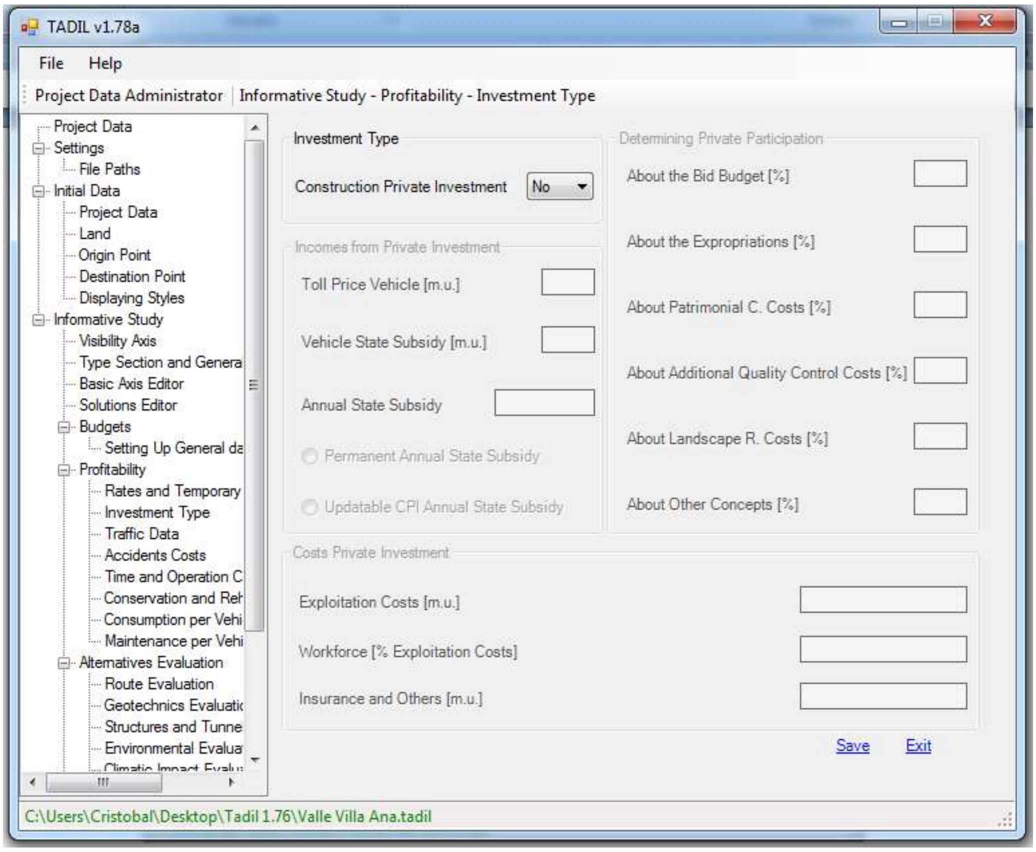


Image 5-10. Menu for the input of information regarding the type of investment.

1.6. Profitability studies

1.6.1. The Annual Updating Rate, the Consumer Price Index and the Construction Price Review Rate.

For the Profitability Study we take into account three things: the Annual Updating Rate, the Consumer Price Index and the Construction Price Review Rate.

The Annual Updating Rate takes into account the update of the value of money over time.

This rate tries to establish the value of the business using the current value of money. Therefore, it is not the same to earn 1,000 euros in the year 2012 than to earn 1,000 euros in 20 years' time, when its value is probably much lower. The value of those 1,000 euros in 20 years' time will be obtained by dividing 1,000 into the Annual Updating Rate raised to the power of 20.

Some economists obtain the value of the Annual Updating Rate with the long-term interest rate of the public debt. Accordingly, if the debt is at 6% for 10 years, we have an Annual Updating Rate of 0.06 (6%).

The Consumer Price Index takes into account the increase of prices and costs.

The Construction Price Review Rate is applied to construction costs and other associated expenses (such as compensatory measures, conservation of the patrimony and landscape restoration) for construction works that take over a year. The review rate is composed of the values of the Consumer Price Index of the materials, workforce and energy used in the construction work. Consequently, the user must make an estimation of its value. These values are generally published by the public administrations in official bulletins.

Before inputting all of this information in the Profitability Study, the user must consider the values and moments of application of each coefficient:

- The **Annual Updating Rate** (UR) is applied from the first year of construction of the infrastructure until the end of the exploitation period considered in the profitability study. When developing the Profitability Study, the promoter will have the option of investing in the new infrastructure or in a fixed interest deposit as an alternative for comparison. Supposing that the construction work begins a minimum of one year after the study was carried out, once the investment starts, the interests that would have been obtained in the alternative investment are lost (1 + UR).

- On the other hand, the investor should forecast a series of expenses and incomes at estimated prices during the first year of exploitation, that is to say, once the construction work has finished. Therefore, the **Consumer Price Index** of all the expenses and incomes will not be applied until the second year of exploitation, and until the end of the exploitation period considered in the study.

- Finally, the **Construction Price Review Rate** is applied from the second year of the construction until the last year, when the construction work is finished. The user should make an estimation based on his or her knowledge of the economic ratios of the country where the infrastructure is being studied. This price review rate is only applied to the costs of the construction work, that is, to the budget report for the administration minus the expropriations, and without VAT.

To sum up:

UPDATING RATE

It is applied (1+UR) from the first year of construction of the infrastructure. During the following years it will have a value of $(1+UR)^n$, where n is the number of years taken to build the infrastructure. The maximum value of n is the sum of the years needed for the construction plus the years of exploitation (n=t+m).

CONSUMER PRICE INDEX

It is applied from the second year of exploitation of the infrastructure. In each year of exploitation, the value is $(1+CPI)^{m-1}$, where m is the number of years since the start of the exploitation.

CONSTRUCTION PRICE REVIEW RATE

It is applied from the second year of construction to the last. In each year of construction the value is $(1+PRR)^{t-1}$, where t is the number of years since the start of the construction work, and the maximum value is the number of years that the construction work is expected to last.

1.6.2. VAT

For obtaining the annual balance sheet of costs and profits, the VAT of expenses and incomes will not be taken into consideration.

1.6.3. Calculation of private profitability

The amount is calculated when the user selects "Yes" in the option "Private investment construction".

The user must indicate the percentage of costs covered by the investment according to the agreement reached with the public administration, particularly regarding the following aspects:

- Base Project Bid
- Expropriations
- Patrimony conservation costs

- Additional quality control costs
- Landscape restoration costs
- Other (such as compensatory measures)

There are many possibilities, and the international experiences in public-private concessions are also very diverse. Therefore, some public administrations demand that the totality of the investment is performed by the private investor, except from expropriations. Other administrations only demand that the construction costs are assumed by the investor.

Next is a summary of the steps followed by TADIL to calculate the profitability ratios:

A. Determining the values of traffic.

It is very important that the user has previously developed an objective traffic study. It is worth mentioning that it is proven to be the most decisive factor in the failure of private road exploitation. A record of high growth of the traffic must be analysed with pessimism, or at least with a realistic analysis of all the risks.

The information on the traffic that the user must indicate is as follows:

- The expected Average Daily Traffic (ADT) of the year when starting the exploitation.

- The percentage of expected Annual Growth Rate (GR) with respect to the first year. This rate is the same year after year, so the traffic each year is:

$$ADT_{\text{year m}} = ADT_{\text{year 1 exploit}} + ADT_{\text{year 1 exploit}} \times GR \times (m-1) \times 0.01$$

In future versions, TADIL will have the option of including the values of the total traffic per year, according to the user's prediction.

- Vehicles absorbed by the new infrastructure (Ab ADT): we imagine a linear variation between the first year and the last year. The user indicates the value in the first year and in the last year of the exploitation. Normally, if the infrastructure is much better than the old connection, at first it will take in a large amount of traffic (with the exception of the local traffic around the old road). However, if there is a large increase in traffic and, therefore, there is a worse service in the new infrastructure, many drivers will go back to using the old connection. According to this, the percentages of absorption of traffic by the new infrastructure will be very high at first, but will decrease towards the end of the exploitation period.

In future versions, TADIL will give the option of including the values of traffic absorption per year (Ab ADT_m) according to the user's prediction.

TADIL calculates de values of ADT in the new connection and the old one from the moment of operation of the infrastructure and during each of the years of exploitation.

B. Number of years. The following values are specified:

- Construction: TADIL divides the investment costs between the years necessary for the construction of the infrastructure, indicated by the user.

- Exploitation: the number of years of study indicated by the user.

C. TADIL calculates the updated Consumer Price Index (CPI) and the Price Review Rate (PRR). During the first year of exploitation the CPI is 1, and from here onwards the values considered are $(1+CPI)^{m-1}$, where m is the number of years since the exploitation began. The construction costs are updated by the value of the Price Review

Rate. The first year of construction the value is 1, and the rest of the years the construction costs are updated by the value $(1+PRR)^{t-1}$.

D. TADIL considers the construction costs divided into the number of years of construction given by the user. TADIL considers the itemized budget report for the administration and applies the percentages given by the user of the costs assumed by the private promoter, for obtaining the investment cost before dividing it into the number of years.

E. TADIL considers the conservation and maintenance costs (CMC) per year given by the user, and the rehabilitation costs per 10 years, that must be carried out by the private promoter of the new infrastructure. From the first to the ninth year there will be maintenance costs, and on the tenth year there will be rehabilitation costs. This is repeated every ten years.

The total conservation and maintenance costs are obtained year after year by multiplying it by the total length of the new infrastructure.

F. TADIL then inputs the exploitation costs (EC).

G. TADIL also considers the costs of the insurance contract, when applicable (IC).

H. Afterwards, TADIL adds all the costs of each year:

$$C_m=(CMC_m)+(EC_m)+(IC_m).$$

I. TADIL multiplies each year by the updated CPI:

$$C_{mR} = (C_m)x(1+CPI)^{m-1}$$

J. Once the costs are calculated, TADIL calculates the incomes (I), which are the annual subsidy for the construction of the infrastructure (IS), the income of the toll (IT) and the vehicle subsidy (VS). The annual income per toll and per vehicle subsidy is obtained by multiplying the amount of traffic absorbed (Ab ADT) by 365 days and by the toll values and state subsidy:

$IT_m + VS_m = (Ab\ ADT_m) \times 365 \times (P + S)$, where P is the value of the toll fare in monetary units without VAT, and S is the subsidy per vehicle given by the administration to the licensed company.

$$I_m = IS_m + IT_m + VS_m$$

Normally both forms of subsidies (IS) and (VS), do not coexist. The modality of the subsidy is determined in the contract with the licensed company.

K. The user indicates if the annual subsidy for the construction of the infrastructure (IS) and the vehicle subsidy (VS) have a fixed annual value or a value that is updated with the CPI. Some public-private contracts establish fixed values that can't be revised, so this possibility is also contemplated in the TADIL software.

When the annual infrastructure subsidy (IS) is a fixed amount, TADIL does not update the investment with the CPI. The same is applied for the vehicle subsidy.

The values of the toll can always be updated with the CPI.

Therefore, the total annual income updated with the CPI is:

$I_{mR}= (1+CPI)^{m-1} \times (IT_m) + (IS_m+VS_m)$, when the subsidy is regular.

Or:

$I_{mR}= (1+CPI)^{m-1} \times (IT_m+VS_m+IS_m)$, when the subsidy can be updated with the CPI.

L. The net value (NV) is the difference between the total annual income and the costs affected by the value of the CPI:

$$(1+CPI)^{m-1} \text{ x } (IT_m) + (IS_m+VS_m) - (C_m)x(1+CPI)^{m-1}, \text{ or:}$$

$$(1+CPI)^{m-1} \text{ x } (IT_m+VS_m+IS_m) - (C_m)x(1+CPI)^{m-1}$$

M. UPDATING RATE (UR). The value is calculated each year, starting from the first year of construction.

$UR_n=(1+(UR))^n$, where UR is the updating percentage given by the user, and n is the number of years that have passed since the construction work began.

N. The updated costs and the updated income are calculated by dividing into the UR value obtained.

$$I_{mA}=I_{mR}/(1+(UR))^n$$

$$C_{mA}=C_{mR}/(1+(UR))^n$$

O. The accumulated value of the income (ΣI_{mA}) and of the costs (ΣC_{mA}) is obtained.

P. Regarding the last year of exploitation, the Net Present Value (NPV) is obtained as follows:

$$\mathbf{NPV= (\Sigma I_{mA}) - (\Sigma C_{mA})}$$

The Benefit/Cost relationship (B/C) is:

$$\mathbf{B/C= (\Sigma I_{mA})/(a\Sigma C_{mA})}$$

The Investment Recovery Period (IRP) is defined by the first year in which:

$$\mathbf{(\Sigma I_{mA})=(\Sigma C_{mA})}$$

Finally, the value of the Internal Rate of Return (IRR) is the value of the updating coefficient in which, at the end of the exploitation period, the costs and the income are equalized.

$$\mathbf{(\Sigma I_{m+t\,A})=(\Sigma C_{m+t\,A}),} \text{ that is:}$$

$$\mathbf{(\Sigma I_{n\,A})=(\Sigma C_{n\,A}),}$$

$$\Sigma I_{n\,A}=\Sigma I_n /(1+(IRR))^n=\Sigma C_{n\,A}=\Sigma C_n /(1+(IRR))^n$$

1.6.4. General or social profitability

The general or social profitability measures the benefits obtained by the road users and the administration for the construction of the new road, for both public and private investment. In the previous section, we have analysed the results of the investment from a merely corporate and private point of view. However, now the evaluation of costs and income tries to calculate the advantages for the users and the administration in purely economical terms.

In this case, the benefits are obtained by comparing the costs with OPTION 0, in which the old infrastructure is maintained and nothing is done.

Therefore, a reduction of costs of any sort in the construction of the new road will imply a benefit.

As a result, the costs of both situations must be obtained:

- Considering that the road is not built (option 0).

- Considering that the new road is built (option or alternative 1).

The procedure that TADIL follows to obtain the ratios of social profitability is as follows:

A. TADIL calculates the **operation costs and time costs** weighted by the percentage of heavy traffic, as explained before, for both the old connection and the new alternative.

Consequently, we will obtain a value of the operation costs + time per vehicle (OCT), selected according to the speed of the road for each year (OCT_m).

This value is applied to the new road: $(OCT_{m})_{nc}$

For the old road, there will be a different value: $(OCT_{m})_{ca}$

If we multiply by the total of vehicles and the length, we obtain the operation costs and time of each infrastructure per year.

$365x(OCT_{m})_{ca}$ $xADT_m$ x L_{ca}, for the option 0 (the new connection is not built).

In option 1, we have the sum of the following operation costs:

$365x(OCT_{m})_{nc}$ $x(Ab\ ADT_{m})$ x L_{nc}

$365x(OCT_{m})_{ca}$ $x(ADT_m$- $Ab\ ADT_{m})$ x L_{ca}

The difference between these values indicates the balance of option 1 with respect to option 0.

Balance of operation and time costs:

$365x[(OCT_{m})_{ca}\ xADT_m \ x\ L_{ca} - (OCT_{m})_{nc}\ x(Ab\ ADT_{m})\ x\ L_{nc} - (OCT_{m})_{ca}\ x(ADT_m- Ab\ ADT_{m})\ x\ L_{ca}]$

B. Costs of accidents

Similarly, the cost of accidents (CAcc) of both infrastructures must have been previously calculated, considering two situations:

Option 0: all the traffic uses the old road, $CAcc_{Op\ 0}$, per year $CAcc_{m\ Op\ 0}$.

Option 1: the traffic is distributed between the old road and the new one, $CAcc_{Op\ 1}$, each year $CAcc_{m\ Op\ 1}$,

The balance of the construction of the new road each year is:

$CAcc_{m\ Op\ 1}$- $CAcc_{m\ Op\ 0}$

C. Conservation, maintenance and rehabilitation costs

In this case, it must be considered if there is a private exploitation of the new connection.

If this is so, there is no difference between these costs before and after the construction of the new road, for the old road.

CMC_{ca} x L_{ca} + CMC_{nc} x L_{nc} = CMC_{ca} x L_{ca} => CMC_{nc} =0 (the costs of the new road are paid by the licensed company).

If there isn't a private exploitation, the conservation and maintenance costs (CMC) are increased.

We will have: CMC_{ca} x L_{ca} + CMC_{nc} x L_{nc}

The balance is the difference between these two options.

When the old road is not maintained, then: $CMC_{ca} \times L_{ca} = 0$.

D. Construction costs and subsidies for private exploitation

The percentages of investment that the licensed company does not undertake must be covered by the public sector. If there is no private exploitation, it is 100%.

The costs of subsidies per vehicle and per year for private exploitation are considered in the alternative 1. If the exploitation is public, these costs are not taken into account.

Note that in the calculation of the private profitability, these costs were considered income:

IS, is now SC (annual subsidy costs).

VS, is now SCV (subsidy cost per vehicle).

Regarding the application of the CPI values, we have to consider the same factors as in the private profitability section.

E. Toll costs in private exploitation

The toll costs (TC) fall upon the citizens in general.

The costs in the alternative 1 are obtained multiplying the toll by the number of users per year.

F. Benefits regarding the jobs created

The number of jobs created multiplied by the corporate costs constitutes a volume of money that reverts to the private company and the society, so it is therefore considered an income (IPJ, Income per Job). This value is inputted in TADIL as a percentage of the private exploitation costs.

G. Balances

Once the CPI rate is applied year after year, we add the previous positive and negative balances.

H. Applying the Annual Updating Rate

As in the case of private profitability, the Annual Updating Rate is applied to all the balances, each year from the first year of construction.

I. Obtaining ratios

These are calculated with the same formula as the private profitability, obtaining the Internal Rate of Return (IRR), the Investment Recovery Period (IRP), the Net Present Value (NPV), and the Benefit/Cost relationship.

1.6.5. Obtaining lists

TADIL allows obtaining summary charts of the alternatives, where the previous ratios are obtained for each of them. It also allows obtaining the itemized Material Execution Budget, the Base Project Bid and the Budget Report for the Administration.

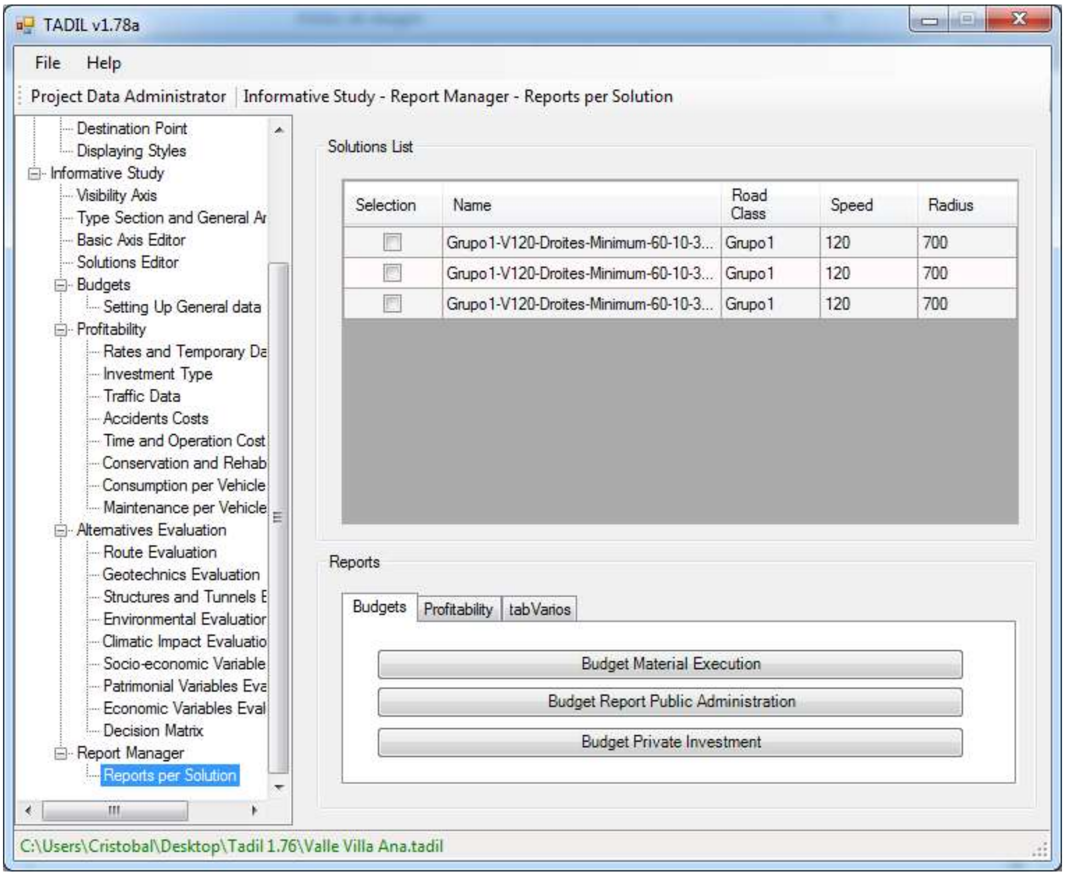


Image 5-11. Menu for obtaining lists of profitability.

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES (TADIL)

CHAPTER 6. VALUATION AND SELECTION OF ALTERNATIVES

ECONOMIC INTEREST GROUP TADIL PROJECT

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES

Methodological Application Guide

CHAPTER 6. EVALUATION AND SELECTION OF ALTERNATIVES

EDITION 1.

The aim of this chapter is giving the user an effective tool for selecting the route alternatives when devising Informative Studies.

The user will have selected several route alternatives that connect the start and end points in the studied territory in relation to certain principles. The user will have to evaluate them jointly according to different criteria.

The variables have a subjective score that allows grading each route alternative. Moreover, by weighting all the scores, a global score is obtained for comparing all of the route alternatives.

The software is interactive so that the user can carry out different analysis and evaluations, give a higher or lower value to specific groups of variables, and create multicriteria studies through the generation of different hypothesis for weighting variables.

CHAPTER 6. EVALUATION AND SELECTION OF ALTERNATIVES

SUB-CHAPTER 0. PROCEDURE.

0. Introduction

This chapter describes the procedure for the evaluation of each route alternative selected by the user. The user will have previously generated and selected a group of alternatives in the Draft Menu, saved with a specific name, as described in Chapter 7.

1. Methodology

When the user reaches this phase of the project, the software has generated the budget and the feasibility study of each route alternative. Similarly, the GIS Menu has been completed, including all the subjective evaluations for each alternative.

With this information, TADIL gives a value to all the route alternatives classified into the following chapters:

- Draft
- Geotechnics
- Structures and tunnels
- Environmental evaluation
- Climatic evaluation
- Socio-economic evaluation
- Patrimonial evaluation
- Economic feasibility

Next we will analyse the evaluation carried out by TADIL of each of the above-mentioned chapters.

1. Route variables that are being evaluated

The route variables valuated in this chapter are the following:

- Draft plan design
- Elevation draft design
- Travel time
- Volume of earthwork
- Earthwork compensation

Next we will analyse these variables.

2. Evaluation of draft plan design

The general criterion is that the larger the draft plan curvature, the better the draft. Therefore, the existence of a larger or lower number of curves is not evaluated, but rather the size of the radius of curvature of these curves.

A draft that has curves with a small radius will generally obtain a lower evaluation. However, a draft with wide curves will be widely accepted, even if the percentage of straight sections is low.

In order to evaluate each axis on the draft plan, a joint evaluation of the whole draft must be carried out. A difference is made between curves, clothoids and straight sections as follows:

- Curves have their characteristic radius (R)
- Straight sections have an infinite radius
- Clothoids have a radius that can vary at each point, between the infinite radius of the straight section and the R value of the curve.

By applying the clothoid spiral formula (explicit formulas), the value at each point is obtained:

$r = A^2/s$, where A is the parameter of the clothoid spiral, s is the length of the arch of the clothoid spiral and r is the curvature.

It is worth mentioning that with the present procedure the quality of the draft is valuated, not the travel time, which is considered as another variable. Consequently, a route alternative can have a high evaluation regarding the draft plan, but a longer travel time than a route with curves with a smaller radius and a worse draft plan design evaluation.

The optimum draft is considered to have a curvature above 2,500 m in 100% of its length.

For evaluating the draft, TADIL obtains a list of the straight sections, clothoid spirals and curves, taking into account the length and radius as follows:

Curves: The length and the radius are considered (L and R).

Clothoids: For each clothoid spiral, the procedure is as follows:

a. The length of the clothoid spiral with a curvature of over 2,500 is obtained, L_{2500}, according to the following formula:

$$L_{2500} = A^2 / 2500$$

b. For the rest of the clothoid spiral, the average radius is obtained according to the following formula:

$$R_{av} = A^2[\text{Ln}(L_e) - \text{Ln}(L_{2500})] / (L_e - L_{2500})$$

where L_e is the length of the clothoid spiral and L_{2500} is the previously obtained length.

Straight sections: The whole line is considered to have a radius of over 2,500 m.

Once the previous information is obtained for the curves, straight sections and clothoid spirals, TADIL does the following:

a. The lengths with a radius of over 2,500 are summed together (straight sections, clothoid spiral sections L_{2500} and curves with a radius of over 2,500). $L_{>R2500}$.

b. The lengths of sections with a radius of under 2,500 are summed together ($\sum$ Lj), (curves with a radius of under 2,500 m and clothoid spiral sections of a smaller radius ($L_e - L_{2500}$)). Afterwards, the percentage (with regard to the whole of the draft) of the segments with a radius of under 2,500 ($Pj = \sum Pi$) is obtained.

c. TADIL obtains the weighted average radius $R_{av<2500}$ of the sections with a radius of under 2,500:

$$R_{av<2500} = \sum [Lj \times R_{av}j] / \sum Lj$$

d. Therefore, the (100 - ½ P) % of the draft will have a radius of over $R_{av<2500}$.

e. TADIL obtains the value: $(100 - ½ P) \times R_{av<2500}$.

f. The score of the alternative with respect to the optimum draft (100% with a curvature of over 2,500 m) is:

$$[(100 - ½ P) \times R_{av<2500}] / 250{,}000$$

g. TADIL compares the scores of the alternatives regarding the one with the best score, which will be given a 0. The higher the score, the worse the evaluation is.

This is for all of the alternatives:

Evaluation of Draft Plan Alternative (Alt) i =10-10 x $[(100 - ½ Pi) \times R_{av<2500}] / [(100 - ½ P_{best\ alt}) \times R_{av\ best\ alt<2500}]$

3. Evaluation of the elevation draft design

TADIL considers that the lower the average slope of the route, the better the evaluation is.

Users generally value soft slopes positively in the drafting of roads, in contrast to strong slopes that reduce the capacity of the vehicles and increase the consumption of fuel.

TADIL carries out a combined evaluation of the whole draft.

The procedure is as follows:

- Each section is considered with its length and slope in absolute values (ABS).

- For vertical curves, the average slope is obtained as follows:

Aver. slope =ABS [Ln (cos(p1))+Ln(cos(-sl2))]/(sl1-sl2)

where sl1 is the slope at the beginning and sl2 is the slope at the end, with its corresponding sign (+ for upwards slopes and – for downwards slopes).

Afterwards, we add all the lengths multiplied by their slope in absolute values, and we divide the result between the total length of the alternative, thus obtaining the average slope of the alternative.

Therefore, the lower the average slope is, the better the score. For obtaining the difference between the alternatives, the one with the lower slope is 0 and the rest obtain their score as follows:

Evaluation of elevation draft Alt_i =MIN (10; 10 x [(av. slope_i – $\text{av. slope}_{\text{alt with lowest slope}}$)/ $\text{av. slope}_{\text{alt with lowest slope.}}$])

4. Evaluation of travel time

This is possibly the variable that the users of the new infrastructure value the most.

For obtaining the travel time, the maximum speed allowed for cars must be taken into account.

The following maximum speeds are considered:

Group 1: 120 km/h (usually corresponds to highways and dual carriageways).

Group 2: 100 km/h (usually corresponds to single carriageway roads).

In the curves, the specific speed included in the table Speed-Radius of the Curvature is considered for each group.

In short, TADIL considers that in the clothoid spirals, the average speed corresponds to the semi-sum of the speed on the curve and the speed on the straight section. This can also be applied for reverse spiral-spirals.

Therefore, the travel time t is:

$$t= \sum L_{\text{straight lines } i} / \text{Speed}_{\max} + \sum L_{\text{curve } i} / \text{Speed}_{\text{specific } i} + \sum L_{\text{clothoid } i} / V_{\text{average clothoid } i}$$

In other words, in the straight sections, the travel time is the distance covered at the maximum speed mentioned earlier (100 or 120 km/h), in the curves it is the distance covered at the specific speed according to the table Speed-Radius of the Curvature, and in the clothoid spirals it is the average between the maximum speed and the speed on the curve.

The alternative with the lower travel time is considered the best. TADIL obtains the scores of the rest of the alternatives as follows:

Evaluation of the travel time Alt_i =MIN(10; 10 x [(t_i - $t_{\text{alt with smallest distance.}}$)/ $t_{\text{alt with smallest distance.}}$])

5. Evaluation of volume of earthwork

The users are generally not aware of the impact of this variable, although it has the utmost importance when considering the complexity of the construction work and, indeed, the impact of earthwork.

For obtaining the volume of earthwork, we add the measures of all the excavation units, of fills and scalings, and of the base courses, both from excavations on site or from borrow pits.

$Vol_{total} = V_{excav} + V_{fill/scaling} + V_{base\ courses}$.

For obtaining the differential score between alternatives, we take the alternative with the lowest volume and apply the following formula:

Evaluation earthwork Alt_i **=MIN (10; 10x[(**Vol_i **-** $Vol_{alt\ with\ smallest\ volume}$**)/** $Vol_{alt\ with\ smallest\ volume}$ **])**

6. Evaluation of earthwork compensation

The volume of earthwork allows us to be aware of the complexity of the construction work. However, there may be a construction work that has a relatively low amount of earthwork but that mostly consists in excavations that have to be derived to the landfill or fillings that come from borrow pits. This would imply a considerable increase in the cost of transport, which would depend on the distance from the landfill and the borrow pit.

This situation could be more unfavourable than another construction work with a higher volume of earthwork in which most of the fillings and excavations are compensated.

Therefore, the earthwork compensation in the construction work must be taken into account.

TADIL adds the volumes of the excavations and obtains the percentage of the excavations that are used on site with respect to the total, that is to say: the sum of the excavations for use at the construction site and the excavations for landfill. The higher the percentage, the better the evaluation is.

The differential evaluation between alternatives is obtained in the following way:

Evaluation earthwork compensation Alt_i **=10-10 x Percentage** $comp_i$ **/Percentage** $comp_{alt\ with\ highest\ compensation.}$

7. Weighting percentages

The weighting percentages that add 100% allow the user to give a higher or lower importance to one or several variables regarding the rest, or even eliminate the weight of a variable.

Therefore, when the route goes through a geotechnical area where the use of materials is not possible, a 0% can be assigned to the variable "earthwork compensation".

Another example can be the study of a rural route in which the travel time is not very important, or a road with a landscape value. In this case, the user applies a very low percentage for the variables of time and design, and higher percentages for the earthwork.

Once the average score of each alternative is obtained, the following formula is applied in order to obtain the scores for comparing the alternatives:

Evaluation of route Alt_i **=MIN(10; 10 x [(Val** $route_i$ **- Val** $route_{alt\ with\ lowest\ score}$**) / Val** $route_{alt\ with\ lowest\ score.}$**])**

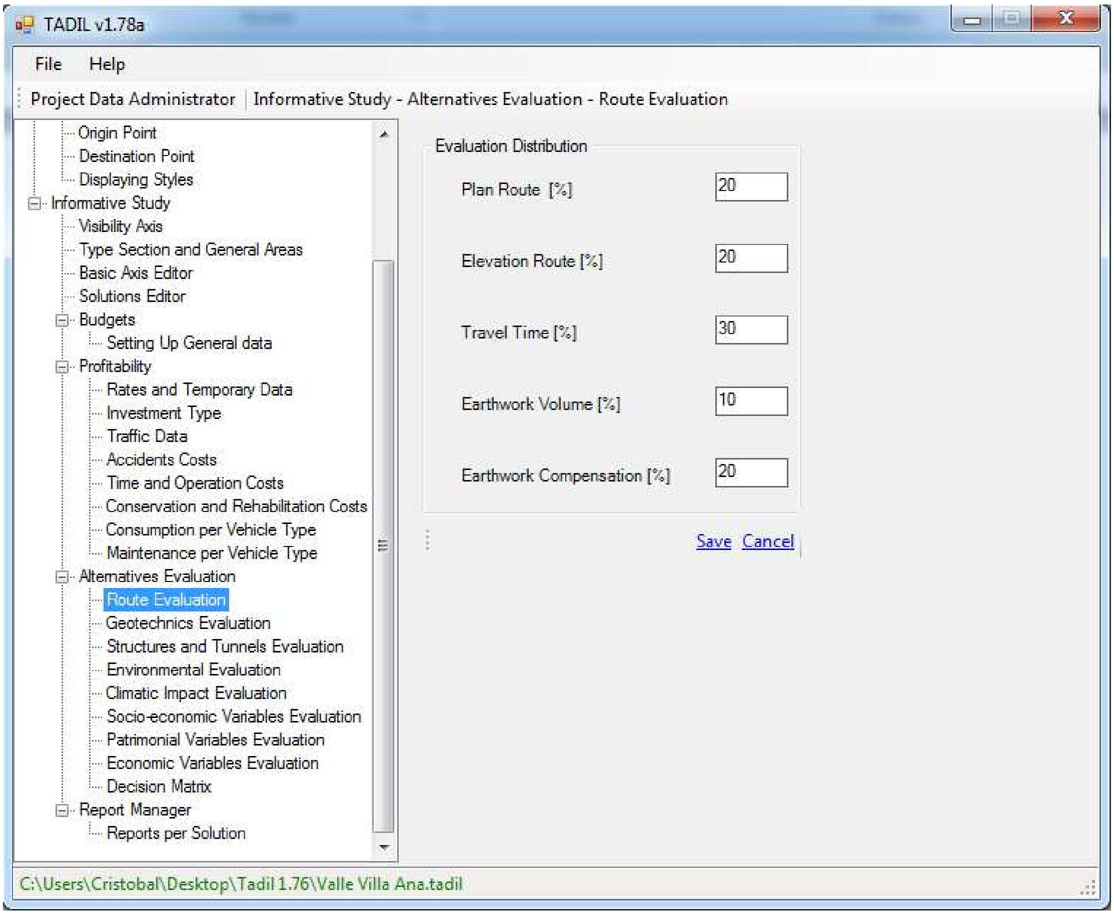


Image 6-1. Weighting draft variables.

SUB-CHAPTER 2. GEOTECHNICAL EVALUATION

1. Route variables that are evaluated

For carrying out a geotechnical evaluation, first there must be a global evaluation of each geotechnical group.

Therefore, the following variables are valuated:

- Horizontal stability of the terrain
- Stability of cut slopes
- California Bearing Ratio
- Evaluation of use of excavated materials
- Excavatability
- Slope protection

2. Horizontal stability of the terrain

TADIL considers that when the acceptable slope of a natural territory for implanting an infrastructure is higher, the better the geotechnical characteristics of that territory is. Therefore it obtains a lower score.

The formula for scoring the alternatives is as follows:

Evaluation of geotechnical area i regarding horizontal stability = (-1/9) x acceptable slope +10

Therefore, for a slope of 90° the score is 0, and for 0° it is 10. Generally, rock masses with no danger of rockslide or active faults allow very high angles, while geotechnical areas with clay, marlstone or similar materials present very low angles.

3. Stability of cut slopes

Another parameter that allows evaluating the quality of the geotechnical group is the stability of the cut slopes. Therefore, a geotechnical group like a rock mass, for instance, could allow implanting a road in a natural territory with a high angle, but in the cuttings, the slopes would have to be reduced to avoid rockslides.

Therefore, it is indispensable that the stability of the cut slopes is taken into account.

The lower the value of the variable "S" inserted in the geotechnical files of the Geographical Information System, the more stable the slope is.

For values above 4, the score is 10, and when S=0, the score is 0.

The evaluation of the maximum height of the cut sections in the axis and the existence of berms or walls is calculated with the following formula:

Evaluation geotechnical area stability slope i: MIN (10; 2.5 S · (C_{hd})· (C_{hbm}))

(C_{hd}) is a coefficient that considers the acceptable height of the cutting. It has a value of 0.5 for heights over 30 m, 0.75 for heights above 20 m and 1 for lower heights.

(C_{hbm}) is a coefficient that considers if there is any need of berms. It is 1.2 when berms are required and 1.5 when walls are required.

4. Value of the California Bearing Ratio

The value of the CBR is a measure of the bearing capacity of soils. Therefore, it is an essential variable in the analysis of the quality of the geotechnical groups: the higher the value, the better the land and, therefore, the lower the score.

The values above 50 have a score of 0, and the values below 2, a score of 10.

Evaluation of geotechnical area CBR i: (-10/48) CBR +(500/48)); with 2<CBR<50.

5. Evaluation of use of excavated materials

The best materials are those which have a higher percentage of excavated materials used in the construction work. Therefore, the best material is that which can be used 100% for the granular layers, 100% for the base courses and 100% for fillings and embankments. In other words, the maximum value is 300 (percent) and its score is 0. The evaluation is as follows:

Evaluation use excavated mat. geotechnical area i: (-10/300) ∑ (%granular layers,%base courses,%fillings) +10

6. Excavatability

In order to value the excavatability, TADIL considers the percentages of distribution indicated in the Geographical Information System.

The previous percentages are weighted according to the score given by the user to each modality of excavation.

TADIL gives the following scores by default:

- Conventional excavation: multiply by 0.
- With a pneumatic hammer: multiply by 3.
- With blastings: multiply by 2.
- With water depletion systems: multiply by 2.75.
- With withdrawal of excavated material in two phases: multiply by 1.75.

Therefore, the maximum value of the weighted percentage is the product with the highest score per 100%, and the minimum value is 0. If the user maintains the scores given by TADIL, the worse one will be 300% (3x100%).

The score would be as follows:

Evaluation excav. geotechnical area i: (10/300) ∑ (weighted percentages)

When it is carried out with the scores given by the user:

Evaluation excav. geotechnical area i: (10/(MAX SCOREx100%)) ∑ (weighted percentages)

7. Slope protection

As in the previous case, the percentages are weighted according to the scores. TADIL suggests the following scores by default:

- Without protection: 0.
- Flexible protections: 1.5.
- Rigid protections or anchorings: 3.

Therefore, with the scores for each geotechnical group the evaluation for each geotechnical group would be obtained as follows:

Evaluation slope protect. geotechnical area i: (-10/300) ∑ (weighted percentages)

If the user wants to modify the previous scores, the evaluation of each geotechnical group would be as follows:

Evaluation slope protect. geotechnical area i: (-10/(MAX SCORE x 100%)) ∑ (weighted percentages)

8. Weighting

The global weighted score of each geotechnical group is obtained with the percentages of distribution of the scores of the geotechnical variables.

In each alternative, TADIL identifies the geotechnical group of each section located along the sequence of metres indicated by the user. A value is obtained for each section: S x geot. val., where S is the separation between the sections, and geot. val. is the score of the geotechnical group.

The average evaluation according to geotechnical criteria of each alternative is obtained by adding the mentioned values of all the sections and dividing the total into the length of the draft plan.

Once the average score of each alternative is obtained, the following formula is applied in order to obtain the scores for comparing the alternatives:

Geotechnical score Alt_i =MIN(10; 10 x [($Val\ geot_{i}$ - $Val\ geot_{alt\ with\ lowest\ score}$) / $Val\ geot_{alt\ with\ lowest\ score.}$])

THIS CRITERION IS APPLIED TO ALL OF THE VARIABLES OF THE GIS.

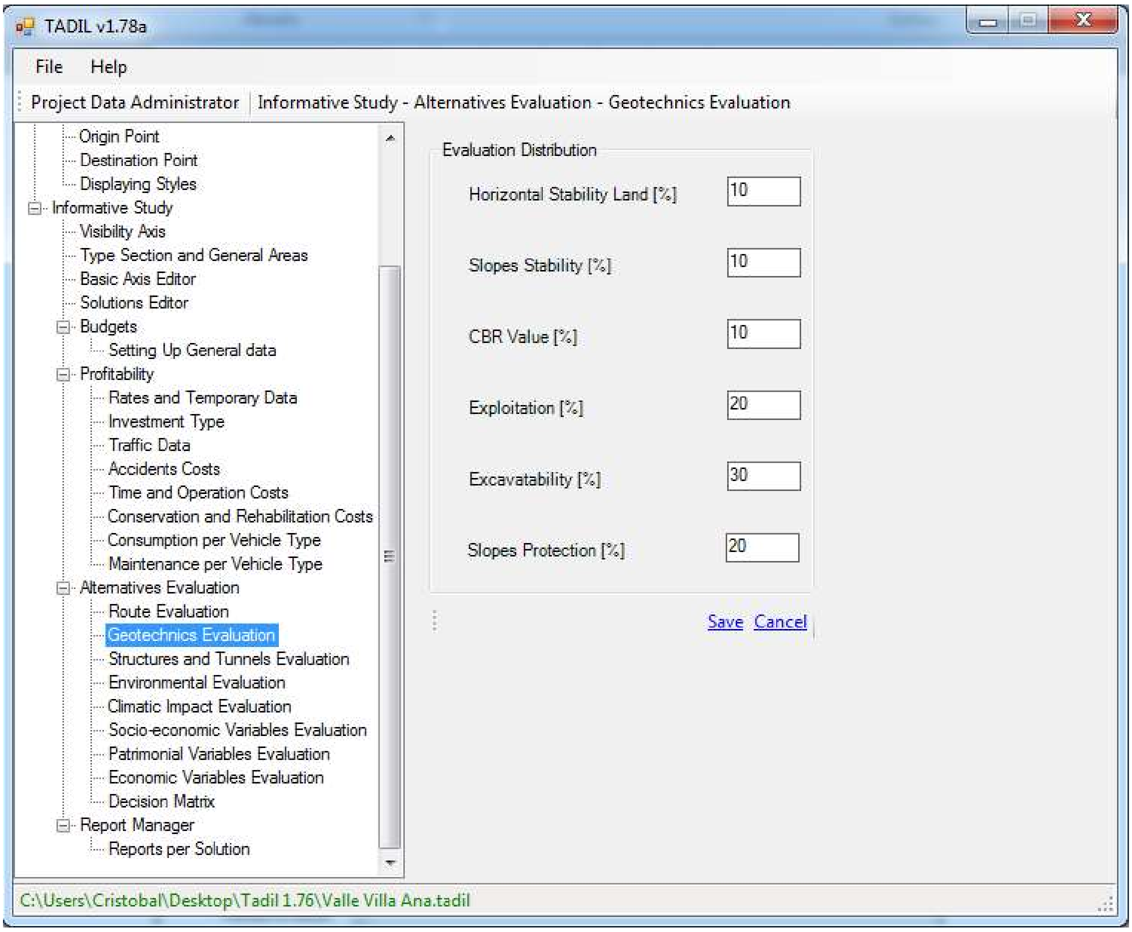


Image 6-2. Weighting geotechnical varibles.

CHAPTER 6. EVALUATION AND SELECTION OF ALTERNATIVES

SUB-CHAPTER 3. EVALUATION OF THE FOUNDATIONS OF STRUCTURES, TUNNELS AND WALLS

1. Variables that are considered

All of the variables related to foundations, tunnels and walls inputted in the Geographical Information System are taken into consideration, particularly the following:

- Foundations of structures:

- Type of foundations
- Excavation method
- Foundations in underpasses
- Presence of water in the excavations

- Evaluation of tunnels:

- Rock Mass Rating Variable
- Tunnel boring methods
- Specific treatments

- Evaluation of walls.

- Volume of walls in the construction work

The following can also be considered:

- A variable that is not taken into account in the score is the selection of the type of viaduct considered for the project. The chosen type has an impact on the budget of the construction work, an aspect which is already included in the multicriteria evaluation.

- The Rock Mass Rating (RMR) variables, excavation methods and specific treatments, as such, are interrelated. However, each of these is independent in order to differentiate geotechnical groups that could have similar RMR but with particularities regarding the methods of construction.

2. Foundations of structures

2.1. Type of foundations

TADIL suggests by default the following scores:

- Shallow foundations: 0.
- Shallow foundations with scalings: 4.
- Foundations with wells: 7.

- Deep foundations: 10.

The user can modify them having in mind that the worse score is always 10 and the best score is 0. In this case, due to the fact that in the GIS Menu only one option can be selected, the score of the geotechnical group regarding this variable is that of its corresponding type of foundations.

2.2. Excavation method

TADIL suggests the following scores:

- Conventional methods: 0.
- Pneumatic hammer: 4.
- Blastings: 6.
- Pile driver: 10.
- Other: 10.

Similarly, the user can edit and modify them considering that the worse score is 10 and the best score is 0.

2.3. Foundations in underpasses

The scores that TADIL suggests by default are:

- Shallow foundations: 0.
- Shallow foundations with scalings: 4.
- Foundations with wells: 7.
- Deep foundations: 10.

As in the previous case, these classifications can also be edited with values from 0 to 10.

2.4. Presence of water in the excavations

Here we analyse the presence of the ground water level above the lowest level of the foundations.

TADIL suggests the following scores by default:

- Non-impact: 0
- Water depletion: 6
- Special systems: 10.

Similarly, the user can edit this information modifying the scores with values from 0 to 10.

2.5. Weighted score of the geotechnics of structures

The global weighted score of each geotechnical group of the structure foundation is obtained with the percentages of distribution of the scores of the geotechnical variables of the structures.

Regarding the alternatives of each section located at the sequence of metres indicated by the user, TADIL identifies the geotechnical group of structures in which the point of the axis is situated. For each section, a value is obtained as follows: S x Val. Geot. Struct. x F_e, where S is the separation between the sections, Val. Geot. Struct. is the score of the geotechnical group of foundation of structures, and F_e is a coefficient of value 1 if in the section a viaduct is planned on the route, and 0.25 when the section goes through a cut or fill.

The average evaluation according to the criteria of geotechnics of structures is obtained by adding the previously mentioned values of all the sections and dividing it by the total length of the draft plan of each alternative.

Once the average score of each alternative is obtained, the following formula is applied in order to obtain the scores for comparing the alternatives.

Geotechnical score structures Alt $_i$ =MIN(10; 10 x [(Val Geot Struct $_i$ - Val Geot Struct $_{\text{alt with lowest score}}$) / Val Geot Struct $_{\text{alt with lowest score}}$.])

3. Evaluation of tunnels

3.1. Rock Mass Rating Variable

The higher the RMR, the better the geotechnics of the land are for boring the tunnel.

The RMR values are between 0 and 100.

The evaluation carried out by TADIL is as follows:

RMR evaluation of the geotechnical area i: (-10/100) RMR +10

3.2. Tunnel boring methods

By default, TADIL suggests the following scores:

- Conventional methods: 0.
- Wall chasers: 2.
- Blastings: 5.
- Slurry Shield TBMs: 8.
- Pressurized shield TMBs: 9.
- Earth Pressure Balance shields: 7.
- Double shield TBMs: 9.
- Other: 10.

The user will be able to edit the scores and modify them with values from 0 (the best score) to 10 (the worst score).

3.3. Specific treatments

By default, TADIL suggests the following scores:

- No need for treatments: 0.
- Treatments presence of water: 8
- Treatments on tunnel face: 7

- Treatments on crown or invert: 5
- Other treatments: 10.

The user can also edit them and modify them.

3.4. *WEIGHTED SCORE OF THE GEOTECHNICS OF TUNNELS*

The global weighted score of each group of the geotechnics of tunnels is obtained with the percentages of distribution of the geotechnical variables of tunnels.

TADIL identifies the geotechnical group of tunnels in each section located at the sequence of metres indicated by the user. In each section, a value is obtained as follows: S x Val. Geot. Tunnels x F_T, where S is the separation between the sections, Val. Geot. Tunnels is the score of the geotechnical group of tunnels, and F_T is a coefficient of value 0 if a tunnel is not planned on the section, and 1 when a tunnel is planned on that section.

The average evaluation according to the criteria of geotechnics of tunnels of each alternative is obtained by adding the previously mentioned values of all the sections and dividing this by the total length of the draft plan of the alternative.

Once the average score of each alternative is obtained, the following formula is applied in order to obtain the scores for comparing the alternatives:

Score geotechnics tunnel Alt $_i$ =MIN(10; 10 x [(Val geot tunnels $_i$ - Val geot tunnels $_{\text{alt lowest score}}$) / Val geot tunnels $_{\text{alt lowest score.}}$])

4. Evaluation of walls

In this case, the higher or lower presence of walls in the cross sections is considered.

The alternative with a smallest amount of walls will have a value of 0.

The variable Wall was already taken into consideration in the geotechnical groups. Given that in many occasions the walls are arranged so as to avoid very long fill sections or extended cut sections (drafting variables), this variable is valued once again, but this time in a quantitative way.

Therefore, the evaluation carried out by TADIL is as follows:

Score Walls Volume Alt $_i$ =MIN (10; 10x[(Vol $_i$ -Vol $_{\text{alt with small volume}}$)/ Vol $_{\text{alt with small volume}}$])

5. Weighted score of walls, tunnels and structures

Once each alternative has a score concerning the criteria for walls, tunnels and structures, the global weighted score of each alternative is obtained according to the weighted percentages indicated by the user for each of these three concepts.

$$\textbf{Score WTS Alt}_i = \textbf{MIN}(10;\ 10 \times [(\textbf{Val WTS}_i - \textbf{Val WTS}_{\text{alt with lowest score}}) / \textbf{Val WTS}_{\text{alt with lowest score.}}])$$

Score WTS is the score of each alternative regarding its walls, tunnels and structures.

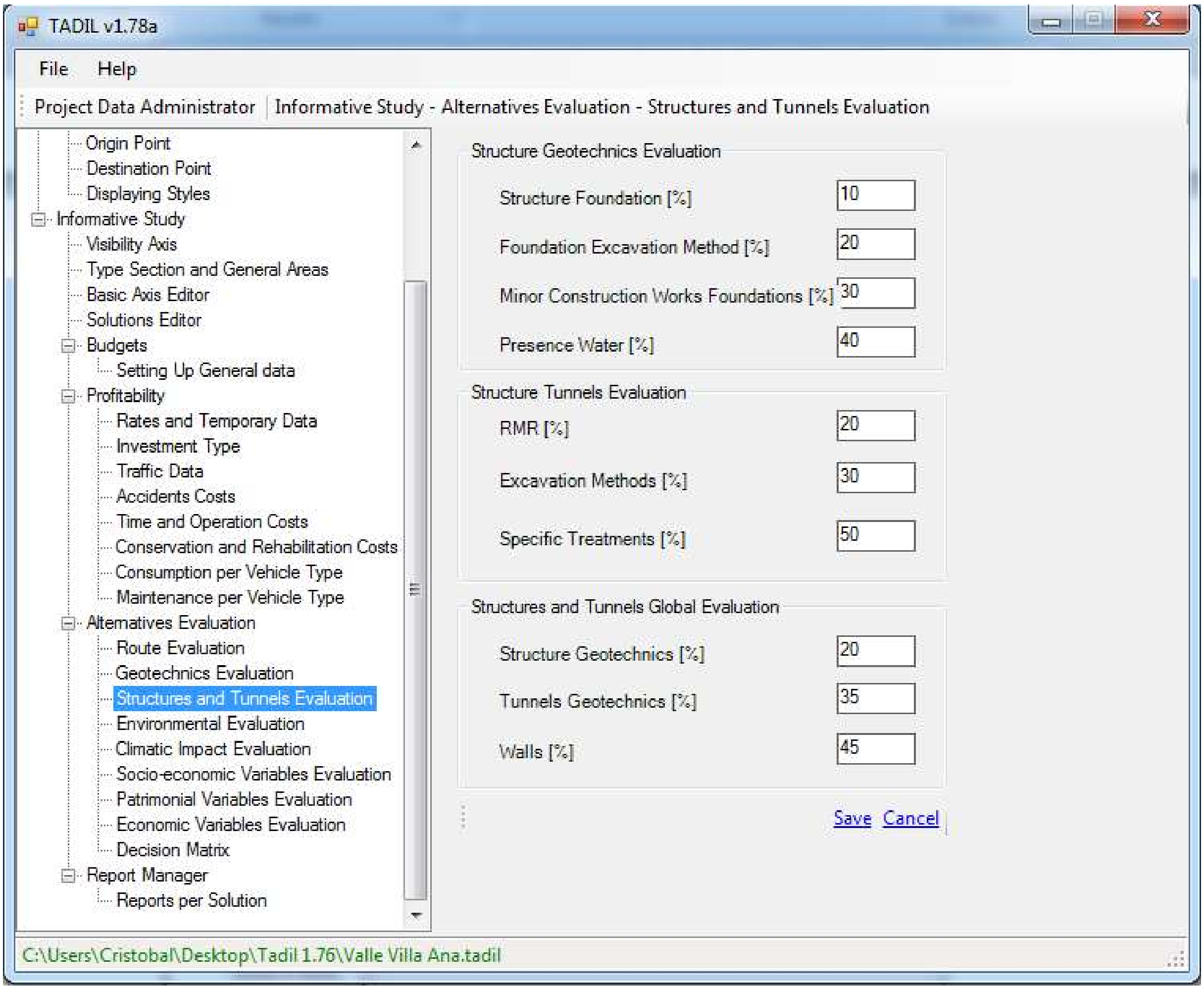


Image 6-3. Weighting of geotechnical variables of structures, tunnels and walls.

CHAPTER 6. EVALUATION AND SELECTION OF ALTERNATIVES

SUB-CHAPTER 4. EVALUATION OF ENVIRONMENTAL, CLIMATIC, SOCIO-ECONOMIC AND PATRIMONIAL VARIABLES.

1. Variables included

This section includes the variables which are divided into four chapters in the Geographical Information System:

- Environmental variables
- Climatic variables
- Socio-economic variables
- Patrimonial variables

The variables included in each chapter are the following:

- Environmental variables:

- Protected areas
- Evaluation of fauna
- Evaluation of flora
- Evaluation of soils
- Hydric and hydrogeological interactions:
  - Areas of public hydraulic domain
  - Aquifers
- Perceptual environment:
  - Areas of Landscape Value
  - Visual fields of interest
- Permeability for the passage of fauna (wildlife corridors)

- Climatic variables.

- Areas of strong frost
- Shady areas
- Areas of frequent storms
- Areas of heavy rainfall
- Areas of frequent snowfall
- Areas of strong winds
- Areas of frequent fog

- Socio-economic variables:

- Primary sector areas
- Secondary sector areas
- Tertiary sector areas

- PATRIMONIAL VARIABLES:

- Public Land.
- Urban Land.
- Building Land.
- Non-development Land.
- Archaeological sites, (different classifications as created by the user, for example, Caution Areas, Places of Cultural Interest, etc).
- Areas of Special Interest.
- Crossing of farm tracks.
- Crossing of infrastructures.
- Areas occupied by public infrastructures.
- Mining or quarrying exploitations.

Most of the abovementioned variables can include several sub-categories, and therefore, a specific point in the axis could have several scores if it is located inside perimeters that correspond to different sub-categories. A point could belong to a Site of Community Importance and a Natural Park area at the same time.

Regarding these variables with sub-categories and with the aim of treating adequately the territorial impacts, the scores for each point of the axis corresponds to the sum in each sub-category limited by a maximum value of 10.

Score variable i in each point = ∑ Value sub-category i < 10

2. Evaluation of environmental variables

As mentioned earlier, TADIL obtains a score at each point of the axis by adding the scores of each sub-category, with a maximum value of 10.

According to this, TADIL proceeds as follows:

- It identifies the sub-categories that have an impact at each point in the axis.
- The score on the sections of each sub-category will be considered.
- In each point, all the scores are added.
- When the value is above 10, a score of 10 is used.
- Afterwards, the separation of the sections (S) is multiplied by the score of the variable.
- The values are added for each section.
- It is divided by the length of each alternative.
- The average score of each variable is obtained.

For obtaining the global score for the environmental variable, the evaluation percentages of each variable included in it are considered. Mainly, the weight of each of the following variables is indicated:

- Evaluation areas

- Soils
- Fauna
- Flora
- Areas of public hydraulic domain
- Aquifers
- Areas of Landscape Value
- Visual fields of interest
- Permeability for the passage of fauna

Once the global score of each alternative is obtained, the scores for comparing the alternatives are obtained by giving a value of 0 to the one with the lowest score (less impact), and obtaining the rest of the scores as follows:

Score environment Alt_i =MIN(10; 10 x [(Val environm $_{i}$ - Val environm $_{\text{alt with lowest score}}$) / Val environm $_{\text{alt with lowest score}}$.])

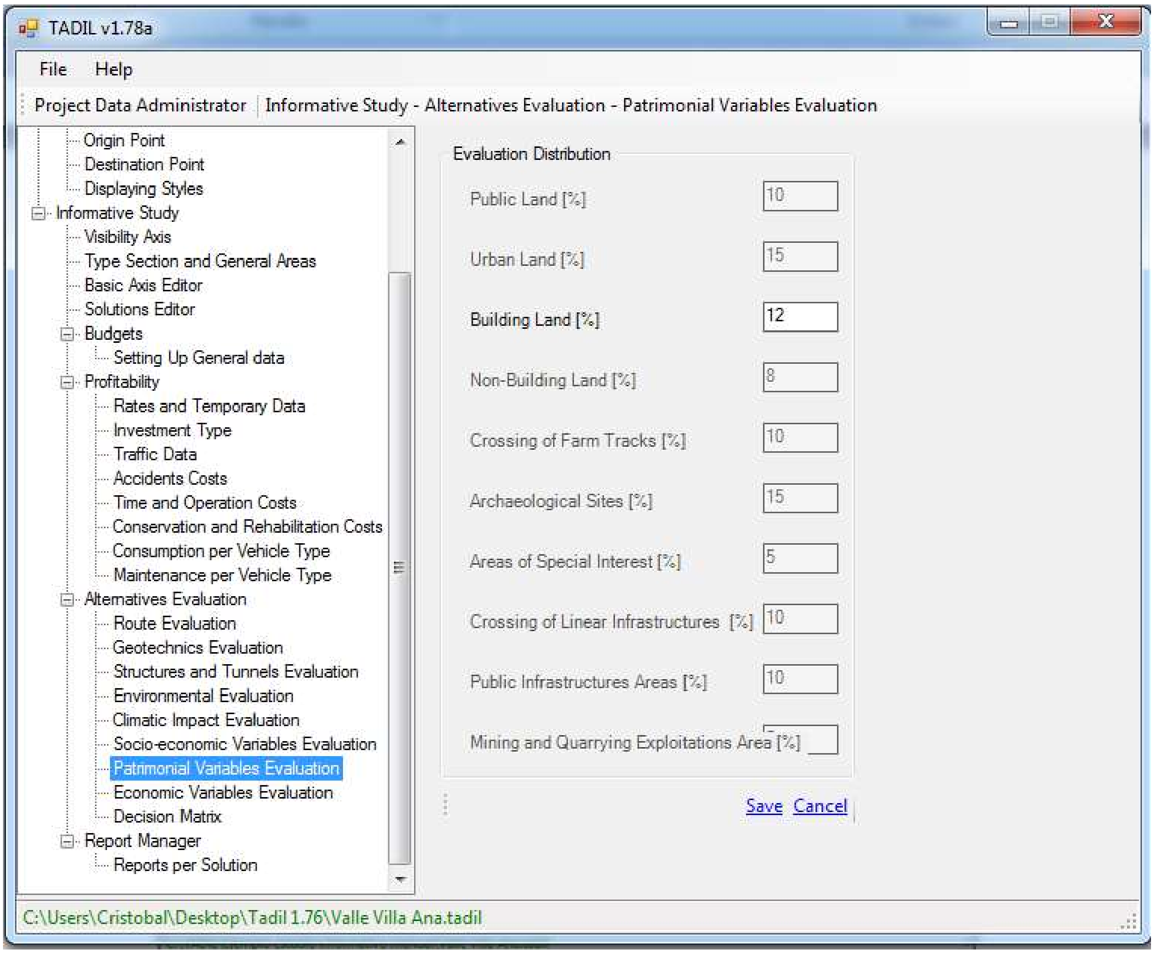


Image 6-4. Weighting of environnmental variables.

3. Evaluation of climatic variables

The procedure is identical to the one indicated for the environmental variables.

Similarly, there could be sub-categories in each variable, so the score would be the sum of all the scores of each of the sub-categories, with a maximum value of 10.

The variables that are evaluated are the following:

- Areas of strong frost
- Shady areas
- Areas of frequent storms
- Areas of heavy rainfall
- Areas of frequent snowfall
- Areas of strong winds
- Areas of frequent fog

The user indicates the weighted percentages of each of the mentioned variables.

Similarly, the comparison of scores of the alternatives is made with reference to the one with the lowest score, which is given a 0.

$$\textbf{Score climate Alt}_i = \textbf{MIN}(10; 10 \times [(\textbf{Val climate}_i - \textbf{Val climate}_{\text{alt with lowest score}}) / \textbf{Val climate}_{\text{alt with lowest score}}])$$

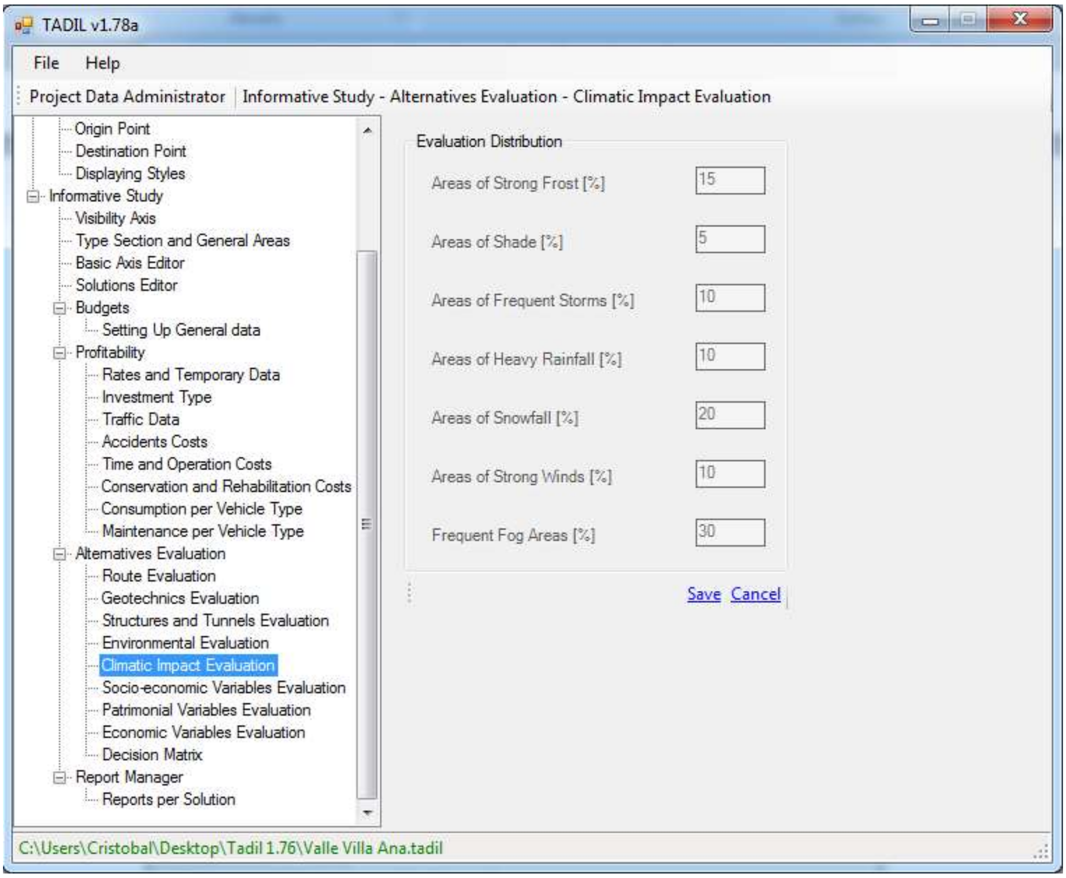


Image 6-5. Weighting of climatic variables.

4. Evaluation of socio-economic variables

In the case of socio-economic variables, sub-categories are not included. Therefore, a point can belong to only one socio-economic sector, with its corresponding score.

The variables that are evaluated are as follows:

- Primary sector areas
- Secondary sector areas
- Tertiary sector areas

The user indicates the weighted percentages of each of the mentioned variables.

Generally, the secondary and tertiary sectors present a higher weight than the primary sector because they have a higher economical productivity.

Similarly, the scores for comparing the alternatives are obtained with reference to the one with the lowest score, which is given a 0.

$$\textbf{Score socio-econ. Alt}_i = \textbf{MIN}(10; 10 \times [(\textbf{Val socio-econ.}_{i} - \textbf{Val socio-econ.}_{\text{alt with lowest score}}) / \textbf{Val socio-econ.}_{\text{alt with lowest score.}}])$$

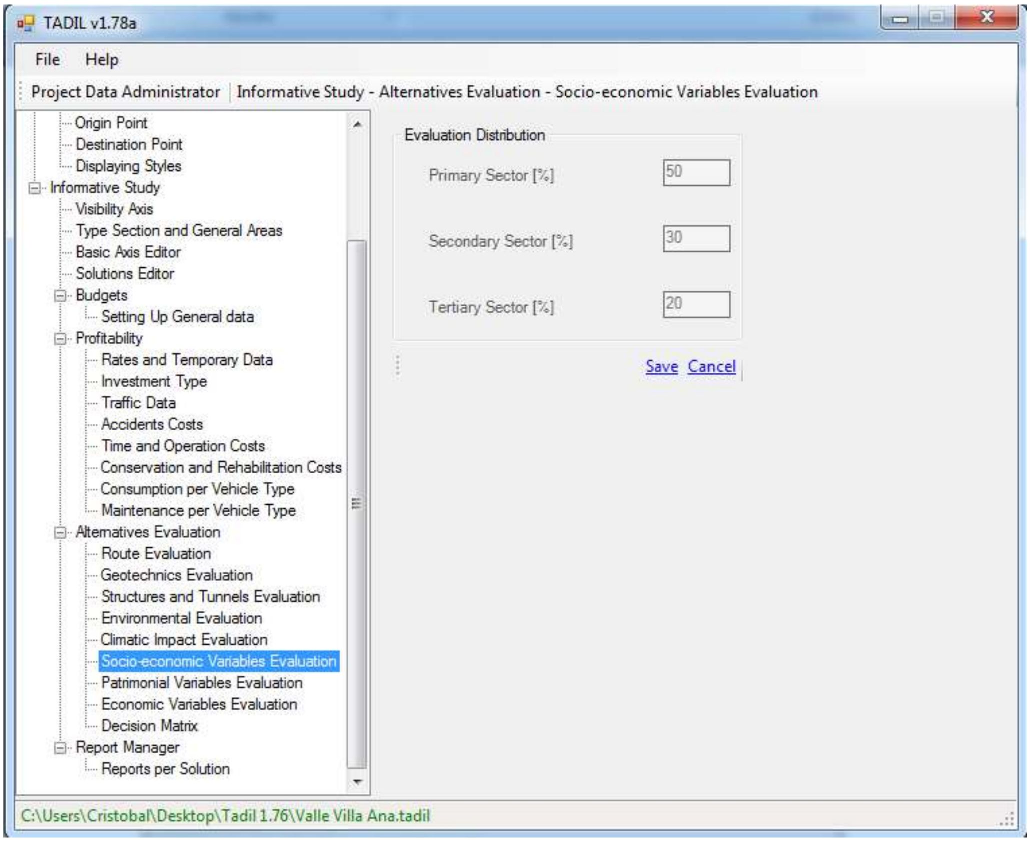


Image 6-6. Weighting of socioeconomic variables.

5. Evaluation of patrimonial variables

In the case of patrimonial variables, some variables do not include sub-categories and others may have several categories. When a point belongs to several different sub-categories, the score corresponds to the sum of all the scores in each sub-category.

The variables that are evaluated are the following:

- Public Land (with sub-categories)
- Urban Land (without sub-categories)
- Building Land (without sub-categories)
- Non-development Land (without sub-categories)
- Archaeological sites (with sub-categories)
- Areas of Special Interest (with sub-categories)
- Crossing of farm tracks (with sub-categories)
- Crossing of infrastructures (without sub-categories)
- Areas occupied by public infrastructures (with sub-categories)
- Mining or quarrying exploitations (with sub-categories)

The user indicates the weighted percentages of each of the abovementioned variables.

Similarly, the scores for comparing the alternatives are obtained with reference to the one with the lowest score, which is given a 0.

Score patrim. Alt $_i$ =MIN(10; 10 x [(Val patrim. $_{i}$ - Val patrim. $_{\text{alt with lowest score}}$) / Val patrim. $_{\text{alt with lowest score.}}$])

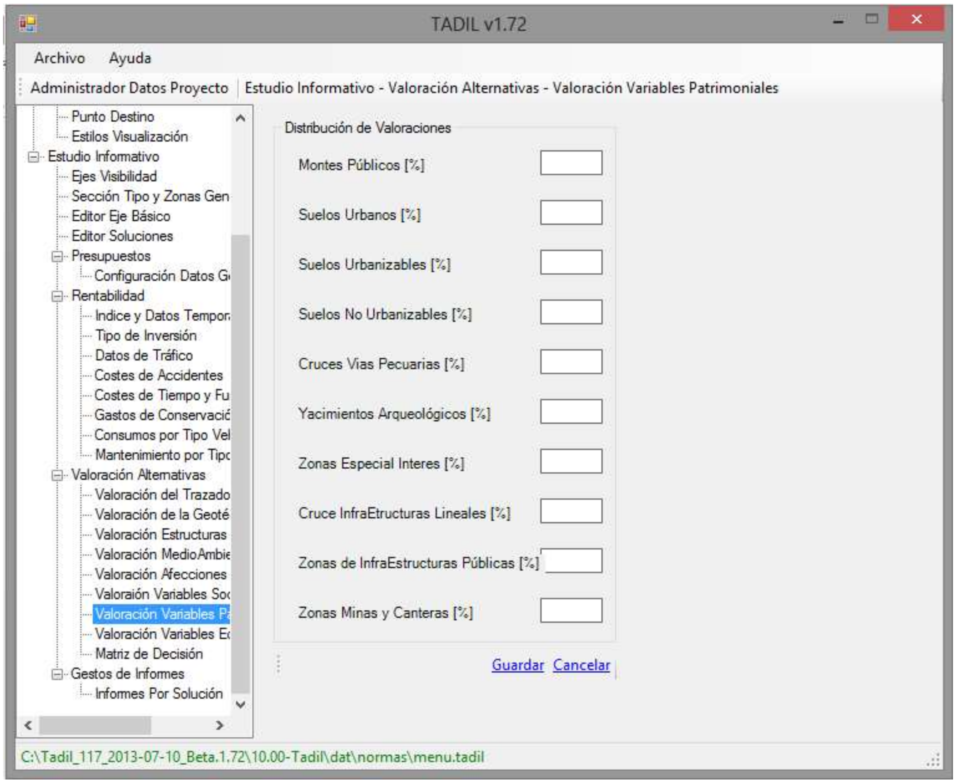


Image 6-7. Weighting of patrimonial variables.

TADIL SOFTWARE
TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES

CHAPTER 6. EVALUATION AND SELECTION OF ALTERNATIVES

SUB-CHAPTER 5. EVALUATION OF ECONOMIC PROFITABILITY.

1. Variables included

Before valuing the profitability, the user must have calculated the economical profitability ratios of each alternative.

In order to obtain a comparative score of the alternatives, TADIL values the Benefit/Cost relationship (B/C) and the Net Present Value (NPV) of each alternative. The scores are also obtained by comparing the alternatives. The one with the highest NPV obtains a score of 0 and so does the one with the highest B/C.

Alternatives with B/C or NPV with negative values are given a score of 10.

When the NPV or the B/C have negative values, the score is directly 10.

$$\textbf{Score NPV Alt}_i = \textbf{If (NPV<0;10;MIN(10; 10 x [(-Val NPV}_i + \textbf{Val NPV}_{\text{alt highest NPV}}\textbf{) / Val NPV}_{\text{alt highest NPV.}}\textbf{]))}$$

$$\textbf{Score B/C Alt}_i = \textbf{If (B/C<0;10;MIN(10; 10 x [(-Val B/C}_i + \textbf{Val B/C}_{\text{alt highest NPV}}\textbf{) / Val B/C}_{\text{alt highest B/C.}}\textbf{]))}$$

TADIL also evaluates the volume of investment needed for the execution of the construction work. The alternative with the lowest investment will have a score of 0 and the rest obtain their score according to the following formula:

$$\textbf{Score Investment Alt}_i = \textbf{MIN(10; 10 x [(Val Investment}_i - \textbf{Val Investment}_{\text{alt lowest investment}}\textbf{) / Val Investment}_{\text{alt lowest investment.}}\textbf{]))}$$

Due to the fact that the investment can be either public or private, the three mentioned variables are indeed six. When private investment is not expected, the checkboxes that correspond to ratios de NPV, B/C and investment are disabled.

Therefore, the user must assign a percentage to each of the previously mentioned variables to obtain de final score of each alternative:

- Private NPV
- Public or social NPV
- Private B/C
- Public or social B/C
- Public investment
- Private investment

With the previous weights, the program obtains a score for each alternative. In order to obtain comparable scores, a value of 0 is given to the alternative with the lowest score and the rest obtain their score according to the following formula:

Score profit. Alt_i =MIN(10; 10 x [(Val $profit_{i}$ - Val $profit_{\text{alt with lowest score}}$) / Val $profit._{\text{alt with lowest score.}}$])

Image 6-8. Weighting of economic variables.

SUB-CHAPTER 6. WEIGHTED SCORE AND SELECTION OF ALTERNATIVES.

1. Scoring of the groups

With the previous process, TADIL will have obtained comparative scores for the alternatives in the following chapters:

- Draft
- Geotechnics
- Structures and tunnels
- Environmental evaluation
- Climatic evaluation
- Socio-economic evaluation
- Patrimonial evaluation
- Economic feasibility

According to the procedure of TADIL, in each of these chapters there is an alternative with a score of 0 which will correspond to the best solution according to the variables included in that chapter.

However, all of the previous aspects should be considered, so the user must assign weighting percentages to each chapter in order to obtain a GLOBAL SCORE for each alternative.

In the Decision Matrix Menu TADIL allows inserting up to three weighting hypothesis.

The user determines the most "politically correct" distribution according to the particularities of the investment, land and infrastructure.

For a private investor the economic feasibility is imperative. For a public administration, the socio-economic and environmental aspects are of first importance, together with the investment. For a building company, the building aspects given by the complexity of the geotechnics, structures and tunnels are essential.

The menu allows obtaining automatically the scores of each alternative indicating the solution with the lowest score.

Finally, in the Lists Menu, TADIL allows obtaining the scores of each alternative broken down into chapters and variables.

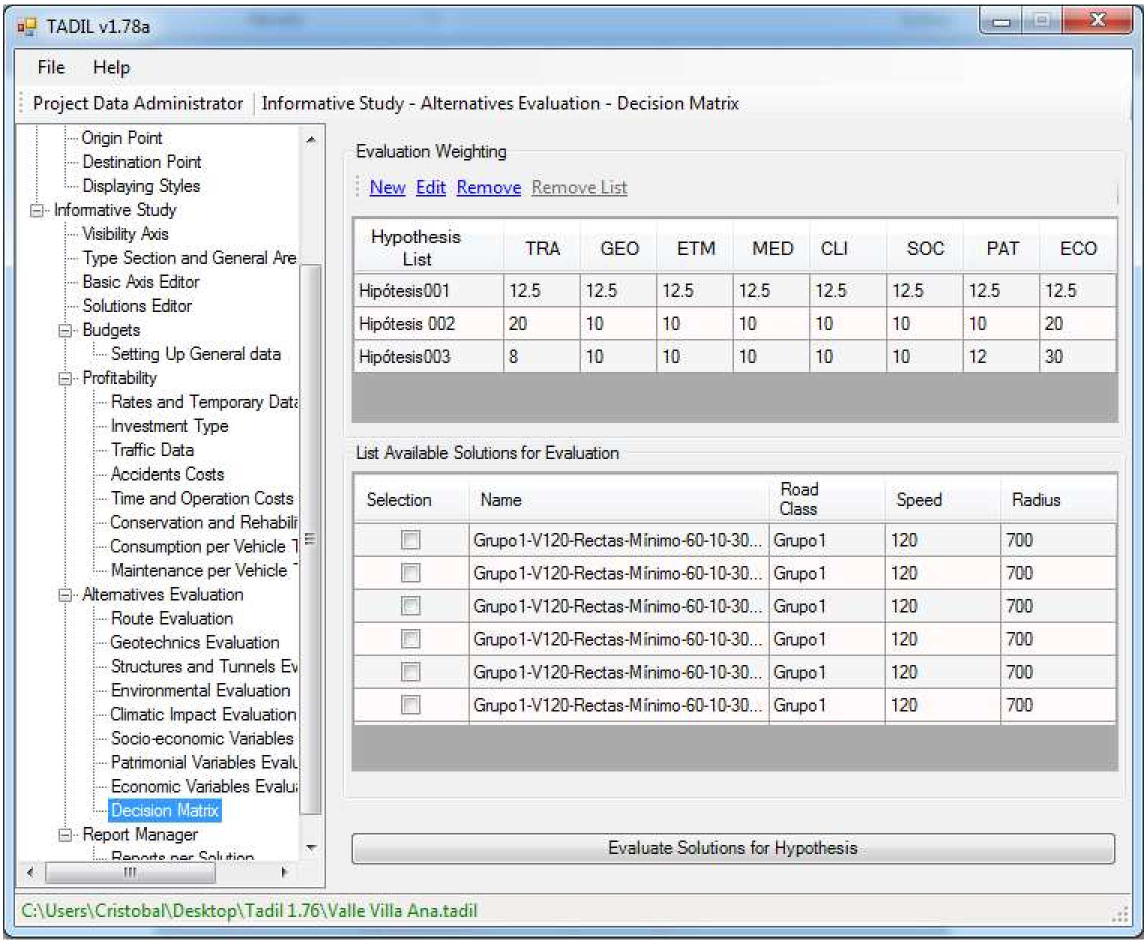


Image 6-9. Final weighted score.

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES (TADIL)

CHAPTER 7. CREATION OF DRAFTS

ECONOMIC INTEREST GROUP TADIL PROJECT

TADIL SOFTWARE

TECHNIQUES FOR THE AUTOMATIC DESIGN OF LINEAR INFRASTRUCTURES

Methodological Application Guide

CHAPTER 7. CREATION OF DRAFTS
EDITION 1.

This chapter includes all the necessary tools for obtaining drafts automatically, including complete axes of the draft, longitudinal profiles, earthwork plans and cross sections.

TADIL includes a wide array of techniques and algorithms that allow creating multiple alternatives in the territory and the optimization of drafts.

This chapter describes the options that the user can choose for creating route alternatives, without going into the conception of the algorithms, which would make the use of the software excessively complex.

The starting point is a digital model of the territory previously created by the user.

CHAPTER 7. CREATION OF DRAFTS.

SUB-CHAPTER 0. PROCEDURE.

0. Introduction

This chapter describes the options in the TADIL software for the creation of alternatives, as well as the possibilities included in the program for creating parametric studies and sensitivity studies of the variables of the draft that provide the best possible analysis of the territory's reception capacity.

1. Methodology

The user must have previously generated the cartography of the project before creating the drafts.

Once the cartography is available, the user can start inputting information for the drafts.

The procedure followed by the TADIL software in the definition of the plan and profile drafts is as follows:

1º Defining the areas of the draft where it is forbidden to cross.

2º Obtaining the visibility axis.

3º Calculating the basic axis.

4º Calculating variations and optimizations of the basic axis.

5º Calculating the axis of the draft.

6º Calculating the longitudinal profile.

The information needed for following this procedure is inserted into the Draft Menu when producing a Previous Study, and when creating an Informative Study, in the Geographical Information System Menu and the Type Sections Menu. Therefore, when accessing the menu, the user must indicate the type of study that is going to be developed.

When the user attempts to analyze exclusively the territory's reception capacity, a Previous Study will be enough. On the other hand, when a complete study is being developed that includes all the territorial variables, an Informative Study should be selected. In this case, the user should have previously inputted the territorial information in the GIS Menu, as well as all the information regarding the type section.

When the user selects the option of an Informative Study, most of the checkboxes of the Draft Menu will be disabled with regard to the Previous Study Menu. This is because the program obtains this information from the GIS and the Type Section Menus.

In the Informative Study option, once the plan axis and profile axis are obtained, the user can obtain the plan design and the cross sections.

Next is a short description of the abovementioned steps:

A. Defining the banned areas.

The areas through which it is forbidden to cross are obstacles for the route. These areas can correspond to areas of the GIS (in the case of Informative Studies) or areas that must be discarded due to their orography or another type of condition (in the case of Previous Studies).

B. Obtaining the visibility axis.

This allows creating a tracker polyline from the start point to the end point, that goes along the edge of the banned areas with the shortest possible length of the polyline, and defines, therefore, a tracker axis for the basic axis.

C. Calculating the basic axis.

It is a polyline that constitues the framework of the draft and it is configured with a geometry that allows its conversion into a conventional axis of the draft.

D. Calculating variations and optimizing of the basic axis.

These techniques allow creating multiple basic axes with the variables defined by the user.

E. Calculating the axis of the draft.

It is a conventional axis of the draft that includes straight lines, curves and track transition curves-clothoids. Its design complies with most of the drafting regulations. The user can select the application regulations.

F. Calculating the longitudinal profile.

This implies the definition of the gradient for the obtained axis of the draft.

The following sections include the definition of the variables that take part in the creation of drafts.

CHAPTER 7. CREATION OF DRAFTS.

SUB-CHAPTER 1. VARIABLES OF THE DRAFT

1. Selection of type of study

The first dialog box that appears in the Draft Menu corresponds to the selection of the type of study. As mentioned in other chapters, the program allows developing two types of analysis which have a different depth and, most particularly, different amount of information on the territory where the implementation of infrastructures is studied.

Chapter 1 describes the difference between the two types of studies.

TADIL allows creating Previous Studies without having to implement the GIS Menu, the Construction Units Menu or the Type Sections Menu. The information is inputted in the Draft Menu.

On the other hand, when the user is developing an Informative Study, the variables must have been previously inputted into the GIS Menu, together with the values of the construction units and the type sections that are to be implemented. Once the information is inserted, the user can access the Draft Menu and create the alternatives.

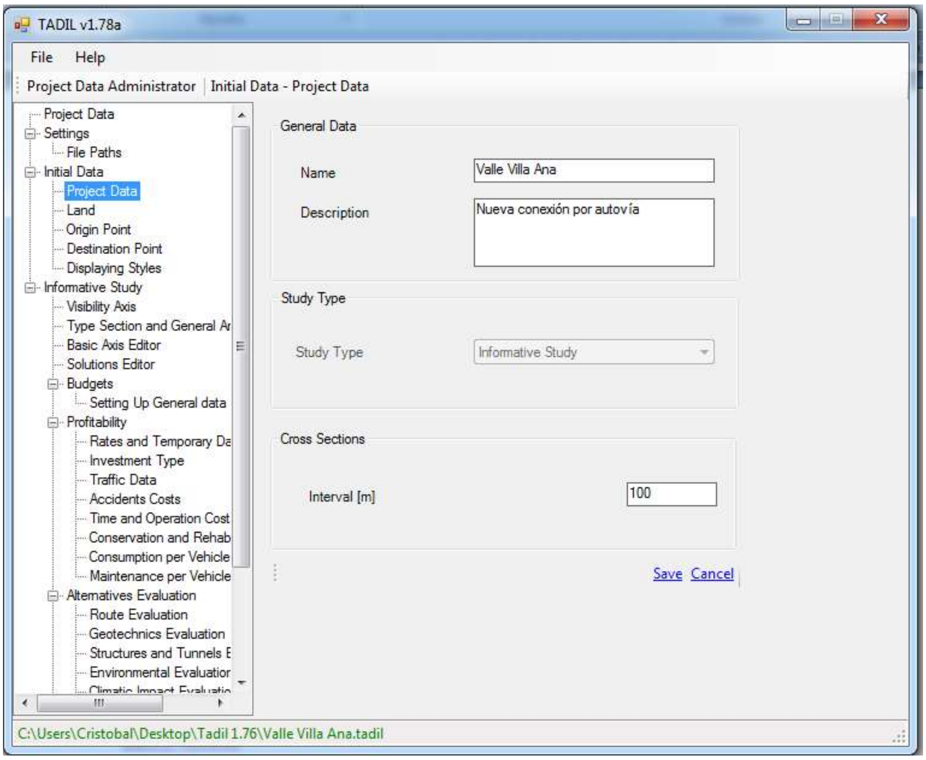


Image 7-1. Project Data.

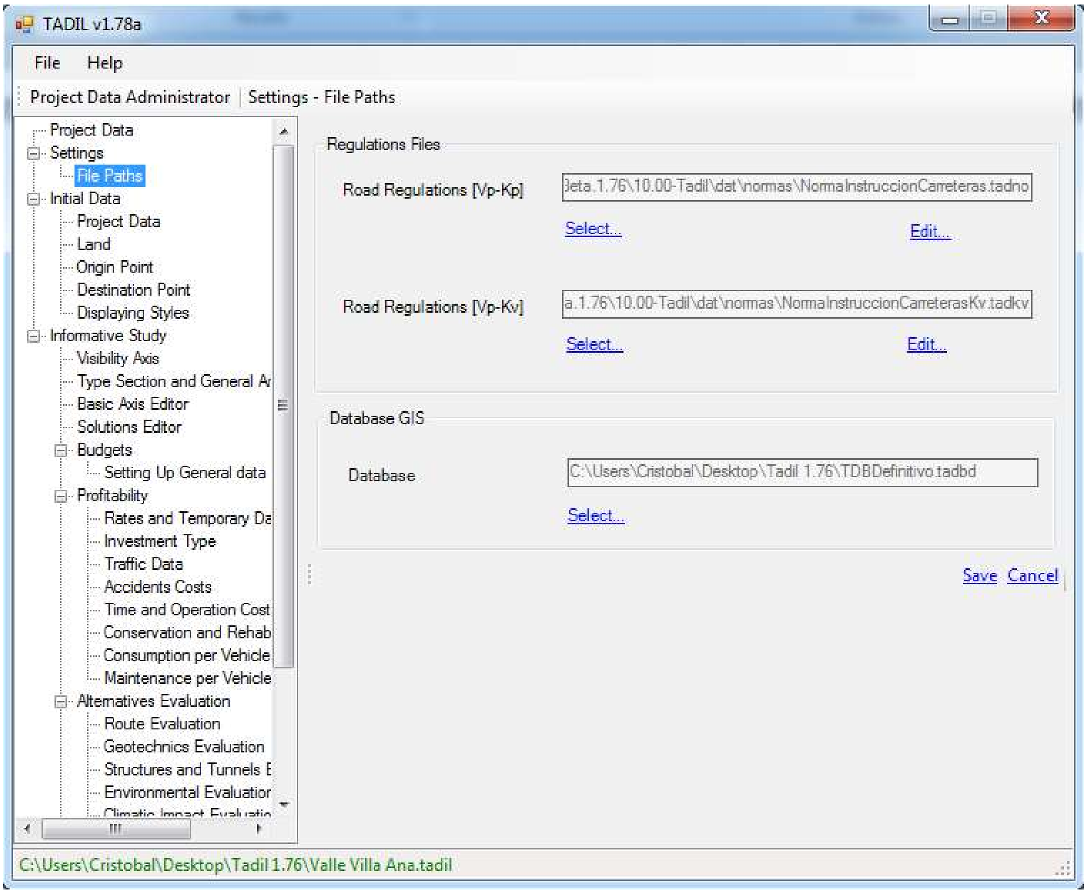


Image 7-2. Selection of regulations.

2. Inserting banned areas

When creating an Informative Study, the program loads the perimeters inserted in the GIS Menu as banned areas. Also, it can create banned areas when the natural slope of the territory is above the percentage indicated by the user. For this, the user must select the option of creating banned areas according to the maximum recommended slopes for each geotechnical group. Also, the user has to indicate a minimum surface of the banned area.

When creating a Previous Study, the user indicates a value of the maximum slope for the whole of the territory and a minimum banned area.

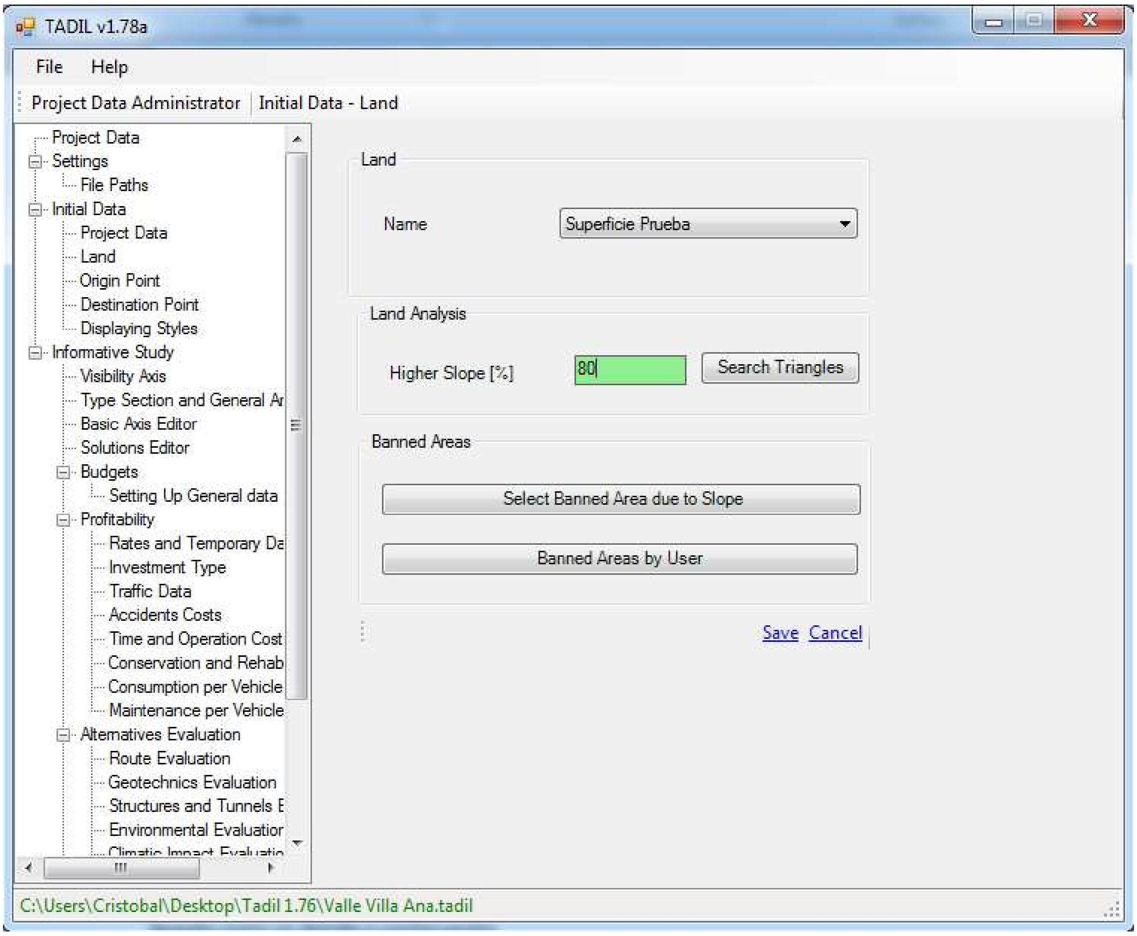


Image 7-3. Specify banned areas.

3. Start and end points

The user can insert graphically the values x,y,z of the start and end points, or insert them directly.

The user can indicate the characteristics of the start and end alignments with the following data:

- Azimuth (measured from the north).
- Length of the start alignment.
- Slope of the start line.
- The user can also indicate the need of maintaining the start alignment as a straight line. If this checkbox is not marked, the transition clothoids between alignments will reduce the length of the start or end points indicated in the previous checkbox. On the other hand, if the user marks this checkbox, the transition clothoids are inserted respecting the length of the straight line. This criteria is useful when a specific tangency has to be maintained regarding an existing infrastructure.

When the slopes at the start and end create cut or fill sections that are higher than those allowed by the user, the program creates the corresponding warning. Similarly, TADIL also creates a warning when, according to the information given by the user, the point at the end of the straight line of the start or end is located outside the cartography.

The checkbox that indicates the length of the starting section cannot be marked without specifying the azimuth, but the azimuth can be indicated without specifying the length of starting section. In this case, TADIL adjusts the straight section at the starting point long enough to connect to the following alignment.

The user can create new alternatives by inverting the start and end points. In both cases, the drafts usually differ at the ends, converging in the central area. The drafts that are short in length could even go through different orographic corridors. The reason for this is that the draft algorithms at the start and end points are geometrically different.

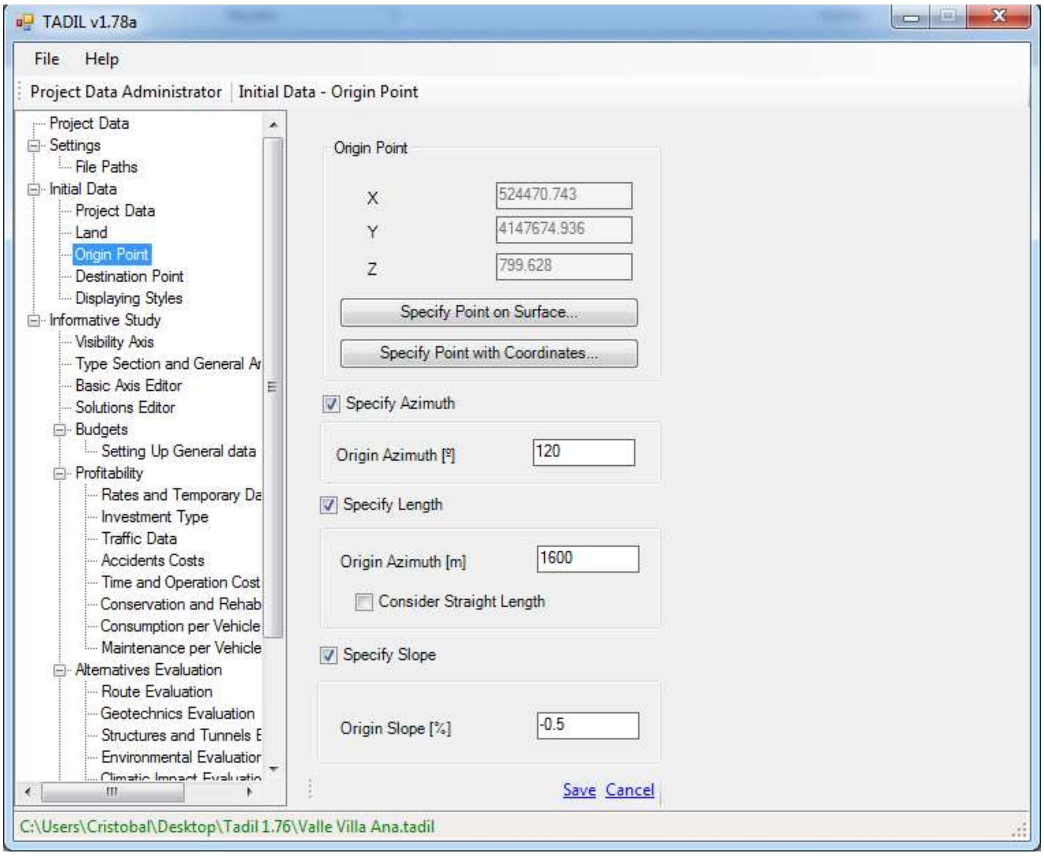


Image 7-4. Entering origin point.

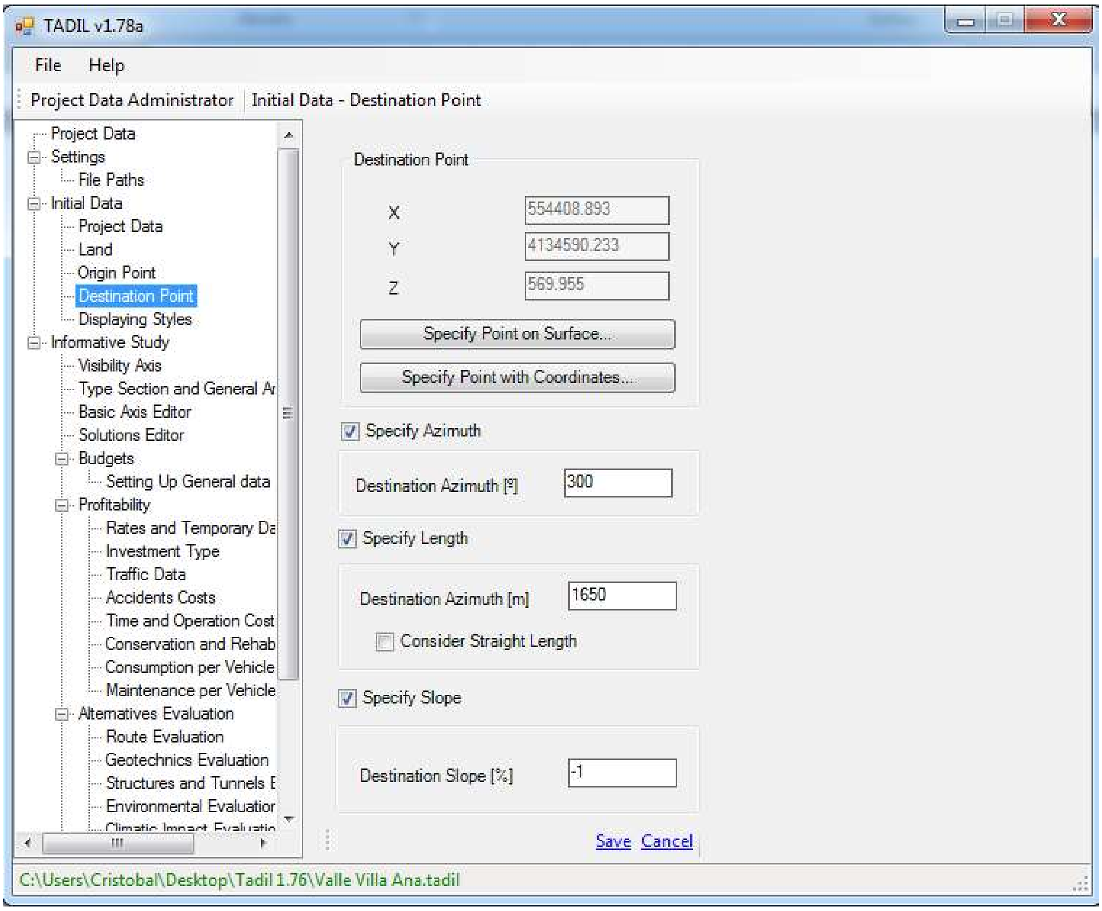


Image 7-5. Entering destination point.

4. Geometry of draft

In this section, the information inserted is different depending on whether the user is creating a Previous Study or an Informative Study.

When creaing an Informative Study, the user only has to indicate the values of maximum and minimum acceptable slope, as well as the maximum and minimum slope of the structures. Finally, the discretization of the axis must also be indicated, which by default is 20 m.

However, when the user is creating a Previous Study, apart from the mentioned variables, the following values must be indicated. They are applied to the whole of the territory:

- Width of the platform in metres
- Slope of the cut section
- Slope of the fill section
- Maximum cut and fill measured at the axis
- Creation of structres and tunnels
- Maximum height of the pier, if structures are allowed

Finally, TADIL allows creating a quick sensitivity analysis by applying a coefficient of reduction of the following variables:

- Maximum slope of the draft
- Maximum height of cut and fill
- Maximum slope of structures
- Maximum height of pier

This tool is very useful for obtaining variations of the drafting parametres for a better quality of the solution.

Let's imagine a road designed for a speed of 80km/h with a maximum of 40m for cuts and fills and maximum slopes of 7%. Once we have obtained the drafts, we could try implementing cuts and fills with a maximum of 30m, thus obtaining new solutions. Next, we could modify the maximum slope to 5%, obtaining new solutions. Finally, we could try a solution with a maximum slope of 5% and a maximum height of 30m, and so on. There could be so many restrictions that it may not be possible to obtain drafts with TADIL. If the possibility of inserting structures and tunnels is allowed, the range of alternatives is very broad, and this provides a wide view of the drafting possibilities.

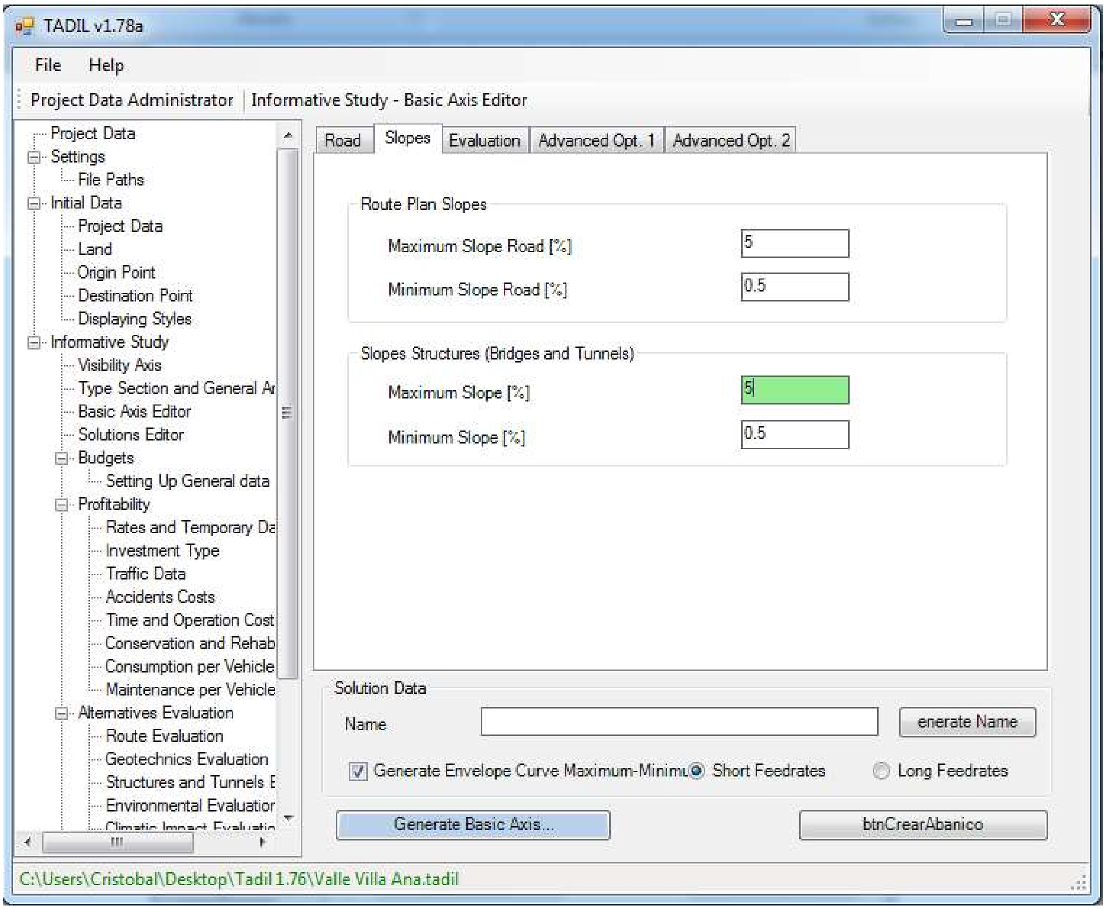


Image 7-6. Maximum slopes.

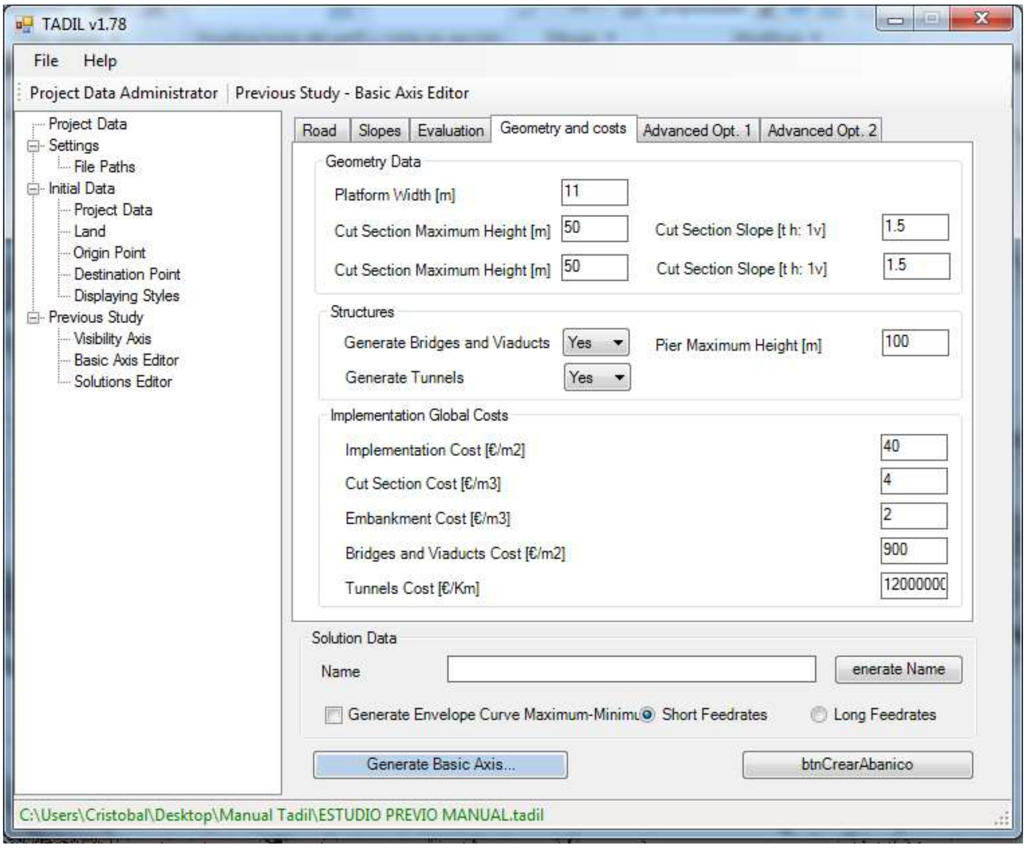


Image 7-7. Geometry and costs in the option Previous Study.

5. Road

In the Road Menu, the user selects the type of road, indicating the group (1 or 2) and the speed of the project in km/h.

Regarding the design variables, the user indicates the preference for drafts with straight lines or curved alignments. The difference between these two cases is described as follows:

- When there is a preference for straight lines, the program tries to implement straight lines with the maximum length possible complying with the regulations, connected by symmetrical sequences of clothoid-curve-clothoid. In the changes of orientation, straight lines are inserted between the clothoids.
- When there is a preference for curves, in S-shaped alignments, S-shaped clothoids are inserted without an intermediate straight line in orientation changes. In turn, the curves are larger (the percentege of draft in curve and clothoid is usually larger).

The following values have an informative nature and correspond to the basic axis of the draft:

- Minimum value in the start and end: the length of the alignment of the basic axis at the start and end points.
- Minimum and Maximum Aij: the minimum and maximum values of the basic axis feedrate in the territory.
- Maximum Aij: the maximum length of the basic axis feedrate when the calculation option "Long feedrates" is selected.

The submenu Advanced Options includes the following:

- Disable sections with length increases above the percentage indicated by the user. This option allows the draft segments to present balanced lengths, limiting the increase of straight alignments with regard to the previous alignment.
- Consider Aij constant. This option implies that all the basic axis feedrates have the same length.
- Tolerance at the target point. This option recommends using a percentage of over 50%, thus making the drafts less winding and straighter. This option allows anticipating the target points of the visibility axis.
- Complete fan angle (°). This refers to the angle of design of the draft options in the local search algorithm.
- Degrees of discretization (°). This referes to the separation of the radials from the draft point in the local search algorithm.

In general, the use of the abovementioned options is mainly for advanced users. It is recommended that the values are not modified except for very specific draft tests.

Finally, for the automatic calculation of the longitudinal profile, the user can select among minimum or maximum values of the vertical clothoid, according to the referenced regulations.

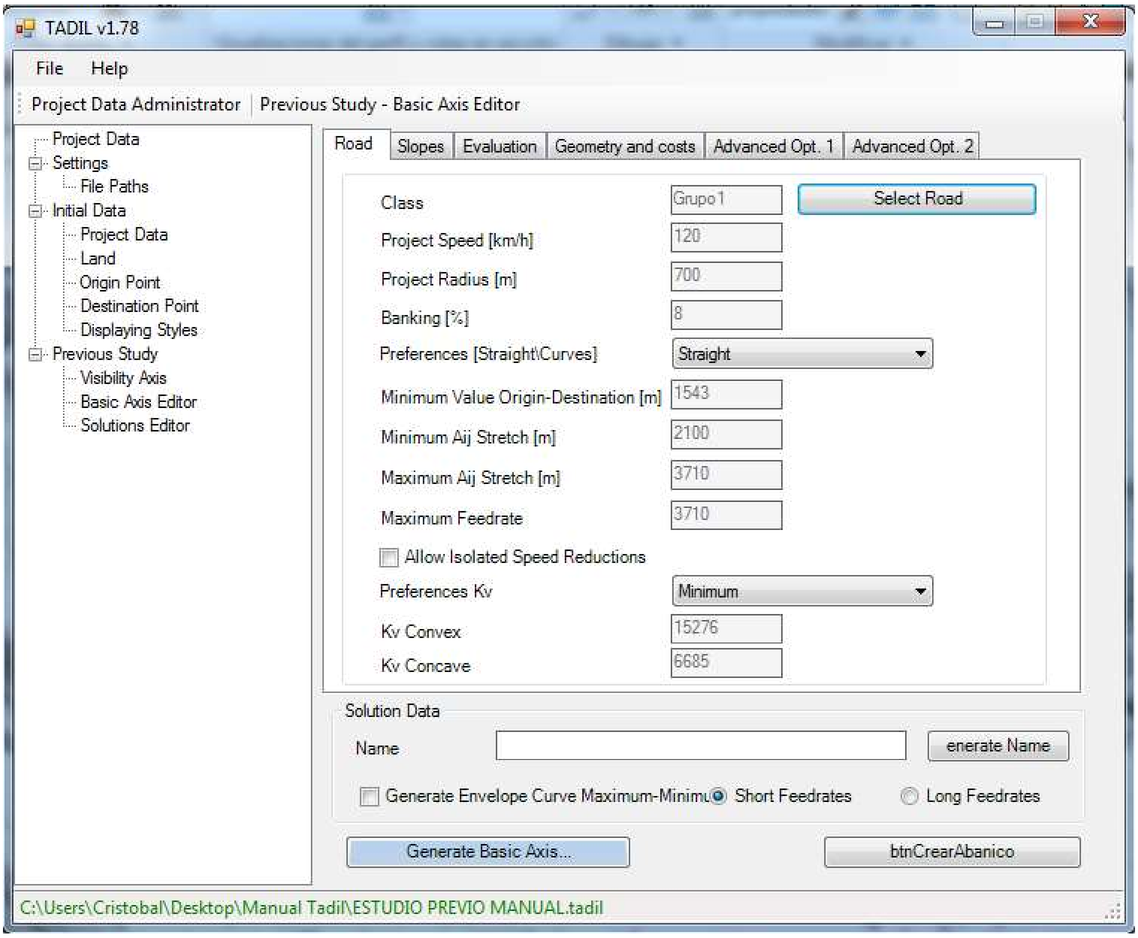


Image 7-8. Infrastructure Data.

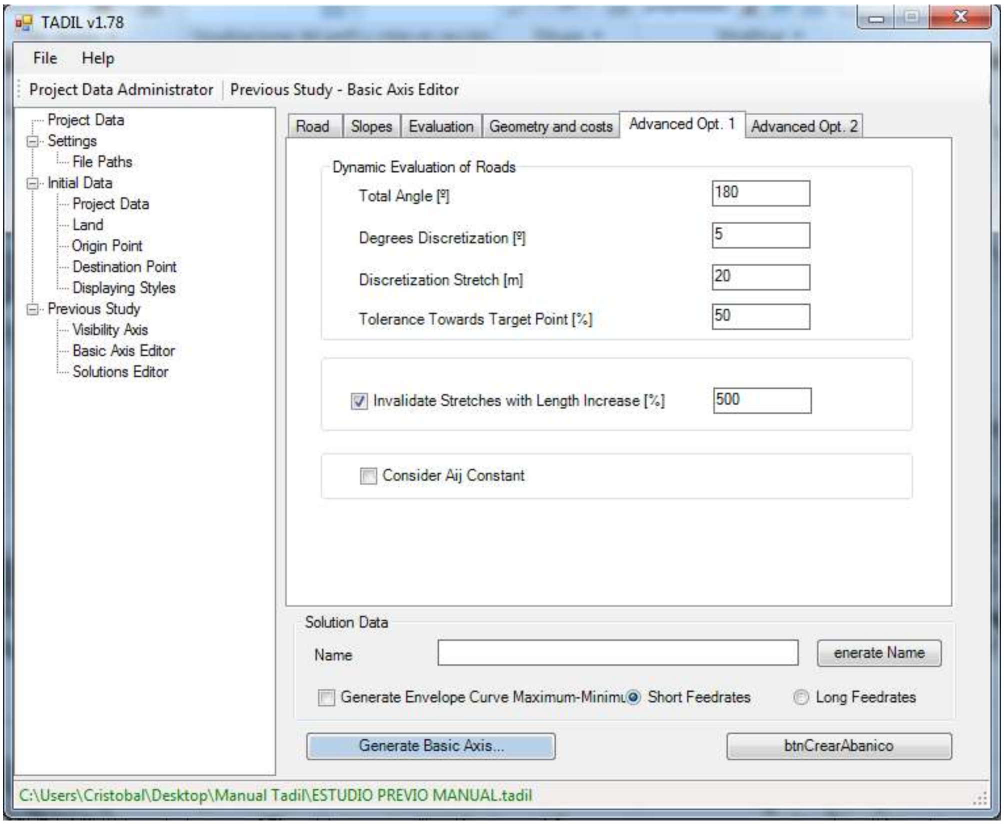


Image 7-9. Advanced Options 1 Menu.

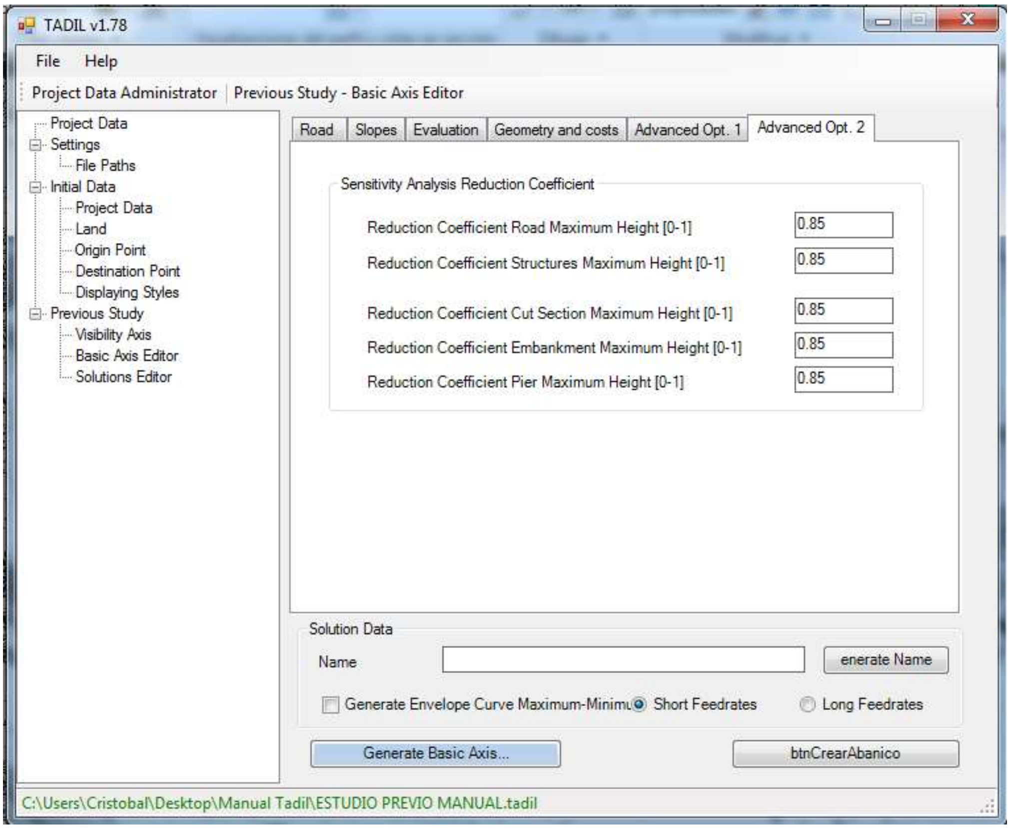


Image 7-10. Advanced Options 2 Menu.

6. Global costs

This menu is disabled in the Informative Study option, due to the fact that the values are obtained from the GIS Menu and the implemented Construction Units Database.

When creating a Previous Study, the user must indicate the following values:

- Cost of implementation: esplanade and superstructure costs, including the pavement required for building the infrastructure. The price is given by the user per square metre.
- Cost of cut: the cost is indicated per cubic metre.
- Cost of fill: the value is indicated per cubic metre.
- Cost of structure: a macro-price is indicated per square metre of the deck.
- Cost of tunnel: a macro-price is indicated per lineal metre.

When the user is creating an Informative Study, TADIL obtains these values as follows:

- Cost of implementation: It is the sum of the cost of the roadbase layers according to the price of each construction unit for the pavement, plus de cost of each layer of the esplanade according to the price of the construction units. This value is obtained at each point of the draft (made by the discretization), according to the geotechnical group created in the GIS Menu that each point belongs to. This cost is expressed as follows:

  $CI=\sum WRb \times PRb + \sum WEs \times PEs$, where:

  CI, is the cost of the implementation.

  WRb, is the width of each roadbase layer, in metres.

  PRb, is the price of each roadbase layer, in euros per cubic metre.

  WEs, is the width of each layer of the esplanade in metres.

  PEs, is the price of each layer of the esplanade, in euros per cubic metre.

- Cost of fill: It is the average value of the cost of fill sections created with excavated material and that of fill sections created with borrowed material, according to the construction unit included in the geotechnical group that the point of the axis belongs to.
- Cost of cut: It is the average value of the cost of cut sections to landfill and cut sections for use in the construction work, according to the construction unit included in the geotechnical group that the point belongs to.
- Cost of structure: It corresponds to the price per kilometre of the deck of the type of structure considered in the geographical area defined in the GIS Menu that the point belongs to.
- Cost of tunnel: It corresponds to the price per linear metre of the type of tunnel included in the geographical area defined in the GIS Menu that the point belongs to.

In the dynamic evaluation of drafts, TADIL does not quantify other construction units such as signalling, drainage, replacements, and so on, because these values are considered similar for all the possible alternatives, and they correspond to the category of infrastructure that is being designed. The final goal is to be able to compare the possible itineraries dinamically regarding the cost of the volume of earthwork, pavements and esplanades or structures and tunnels.

7. Dynamic evaluation of the alternatives

In the dynamic evaluation of the alternatives, TADIL considers three factors:

- Proximity to the end point.
- Orography of the territory where it is to be implemented, given by the maximum slope of the digital model of the territory.
- Global cost.

The user should indicate the weighting percentages that add up to 100%.

In most drafts, priority is given to the cost of the infrastructure, then to the proximity to the end point and, lastly, to the orography of the implementation.

If the user gives 100% of the weighting to global costs, the draft obtained would probably have a lower volume of excavations, but the route would be less direct than if there was a percentage of evaluation given to proximity.

If the evaluation gives 100% of the weighting to the proximity to the point of end, the route obtained would be very direct, but with higher construction costs.

Finally, the input of variables of the orography of the territory allows giving priority to the implementation of drafts in more level terrains. If this variable is combined with that of banned areas due to a steep slope, we obtain drafts with implementations on more level areas, easier for construction work. This variable should generally not be worth more than 30%. The values between 10% and 20% imply a parameter of quality in the design of the infrastructure.

The percentages of the previously mentioned variables can be modified according to several hypothesis to obtain multiple alternatives throughout the territory, increasing the level and thoroughness of the study. In Informative Studies, these alternatives can be analysed with a multicriteria evaluation.

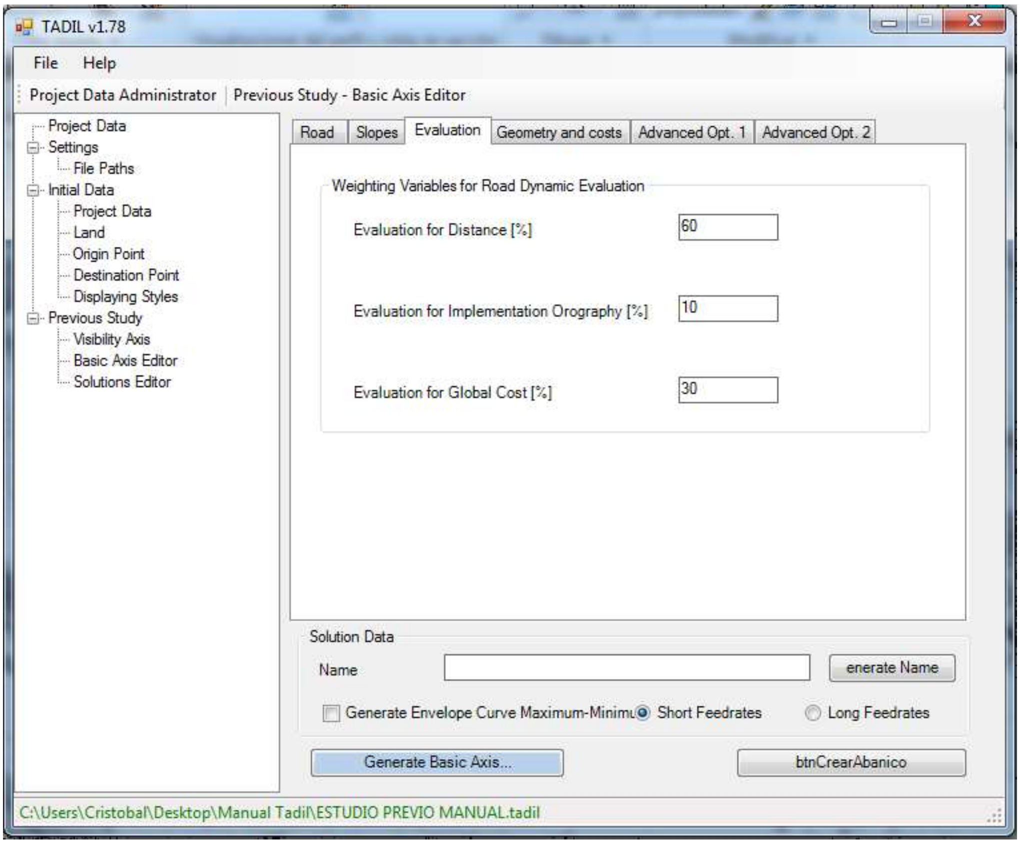


Image 7-11. Dynamic evaluation criteria.

8. Target points and manual visibility axis

The target points indicate the line along the territory that we intend our draft to follow.

TADIL allows inserting up manual visibility axes such as polylines whose vertex are the target points. The user must locate these points in orographical spots that are not located in banned areas. Similarly, if the user creates banned areas in precipitous spaces with a steep slope, the target points should not be situated on these areas, because they will be deleted.

The target points allow drawing the routes towards the desired points, without necessarily having to cross them.

The target points imply not using the automatic visibility axis of the draft.

Moreover, the target points can have a double objective, which consists in making a draft search through different itineraries than those optimum ones given by the algorithm. Therefore, the user can calculate different alternatives and save them. By modifying the target points we can obtain solutions that go through other routes, optimising the study of alternatives.

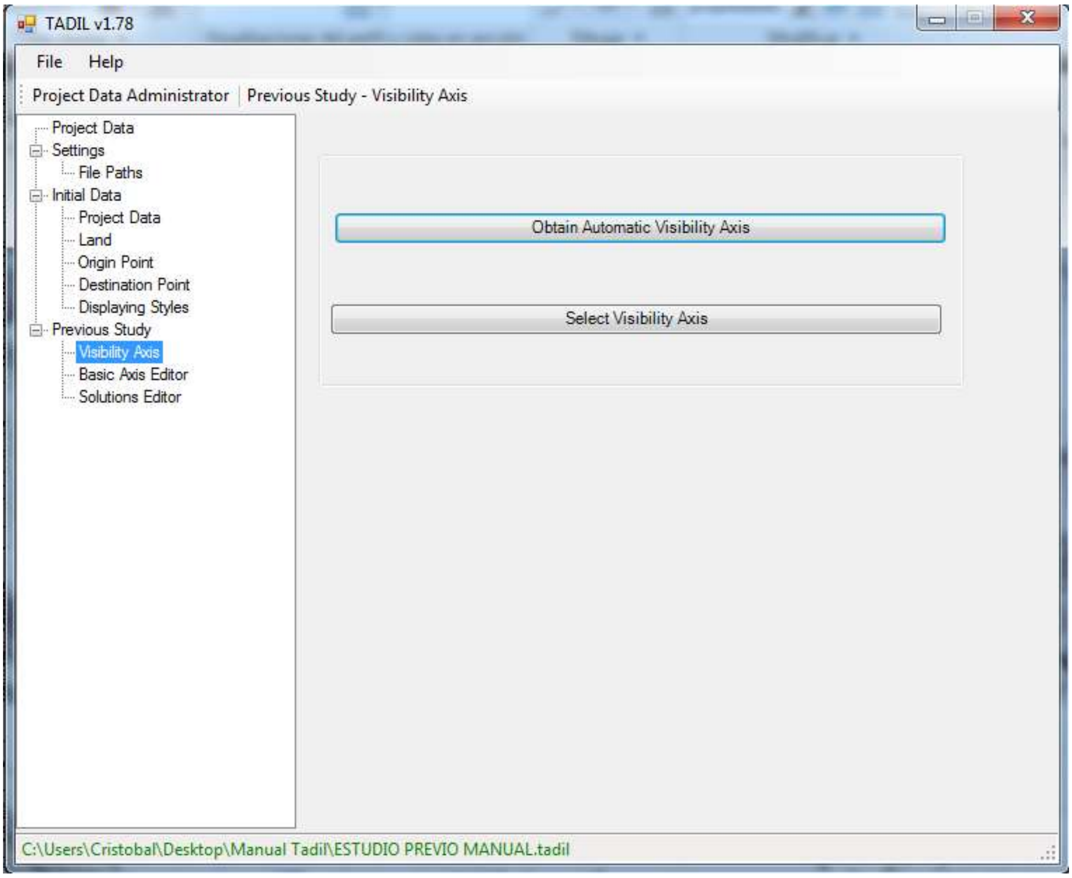


Image 7-12. Automatic or manual (target points) visibility axis

CHAPTER 7. CREATION OF DRAFTS.

SUB-CHAPTER 2. CREATION OF DRAFTS

1. Draft calculation procedure

For both the Informative Study and the Previous Study, the user can create route alternatives in the territory.

The user can choose between two general ways of obtaining drafts:

- Short feedrates
- Long feedrates

The difference lies in the local draft search procedure in the territory:

- By following the short feedrates procedure, we obtain alignments that are better adaptated to the territory, with alignment lengths that comply with the regulations.
- By following the long feedrates procedure, we obtain alignments with the maximum length allowed by the regulations, and a simpler route with less alignments. Although at first this draft may generally seem more attractive, it will require a higher investment than those routes obtained with short feedrates.

In both cases, once the first alternative is calculated (the parent alternative), there ia a series of optimization envelope curves that generate two child alternatives: a maximum envelope curve and a minimum envelope curve.

In both of these child alternatives we obtain the points of the envelope curve of the basic axes of the draft of the parent alternative. The child alternative of maximum envelope curve is obtained by orienting the itineraries toward those maximum points. Similarly, the minimum envelope curve is obtained by orienting towards the minimum points. Therefore, the maximum and minimum points become target points. In some cases, there is a clear optimization in the length of the draft.

By applying one of the procedures (short or long feedrates) and obtaining the maximum and minimum envelope curves, , the user can obtain three child alternatives per parent alternative. Moreover, if we apply the two procedures and their envelope curves, the child alternatives are a total of six.

Finally, the user can enable the option "Allow breaches of regulations in twists and lengths". With this function, the study of itineraries is easier, simplyfing the route search. In the second stage, this option can be disbaled if the user wishes to comply more with the regulations.

In the following section, we will describe how to increase considerably the number of alternatives.

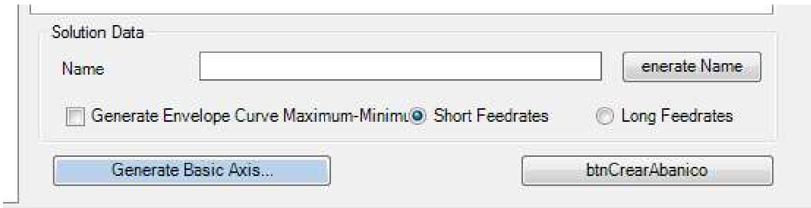


Image 7-13. Creation of drafts.

2. Procedure for the creation of alternatives

As we have mentioned in the previous section, with a parent alternative up to six child alternatives can be obtained.

In order to improve the capacity of analysis and make the most of the possibilities of TADIL, the user can generate new files by modifiyng the variables that are input in the program. Especially, the user can analyse the effect of modifying the following variables:

- Geometry: modifying the values of maximum cut and fill, maximum height of the pier, maximum slope of the draft and structure, directly or by applying coefficients of reduction.
- Type of road (speed of the project).
- Switching the start and end points.
- Modifying the weightings in the dynamic evaluation of the drafts.
- Inserting target points in the territory (manual visibility axis), which will allow the creation of itineraries through other corridors.

For each modification, the user will save the name of each parent alternative. Child alternatives can also be produced with envelope curves, and results can be obtained for long and short feedrates.

As we can see, by applying this procedure, the user can create hundreds of alternatives in the territory.

CHAPTER 7. CREATION OF DRAFTS.

SUB-CHAPTER 3. OUTPUT

1. Obtaining information

The information of the alternatives that can be obtained by the user will depend on the type of study:

- In a Previous Study, the user can obtain a graphic axis of the draft plan and the longitudinal profile, as well as the listings of plan and profile.
- In an Informative Study, the user can also obtain a plan drawing of the earthwork and the cross sections.

In an Informative Study, once the draft is calculated, the user can obtain the listings, the earthwork balance and the budget in the Budget Menu, the economic feasibility in the Profitability Menu, and the multi-criteria evaluation of the selected alternatives.

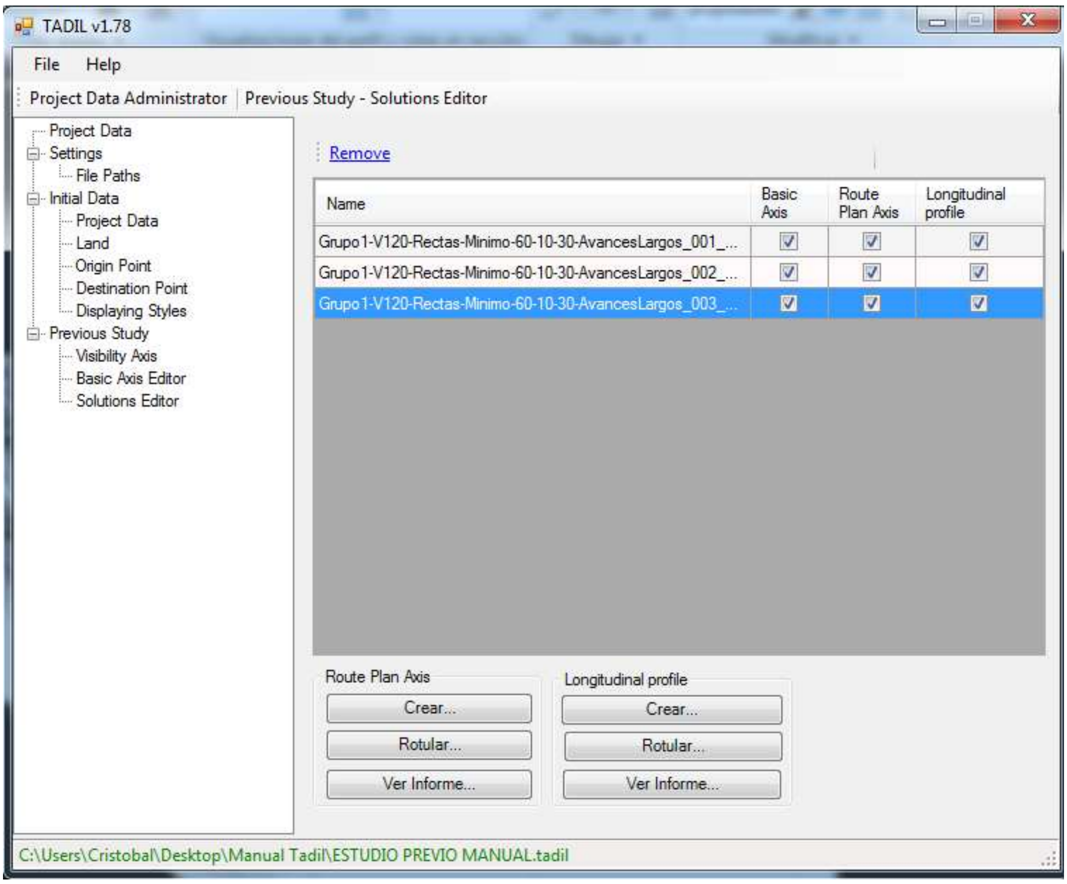


Image 7-14. Output menu.