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Procedia - Social and Behavioral Sciences 160 (2014) 102 – 111

Procedia
Social and Behavioral Sciences

XI Congreso de Ingeniería del Transporte (CIT 2014)

Possibilities of *RutasOptiRed* package

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Abstract

Planning the operations of *Renfe Operadora* trains on *Adif*'s (Spanish) railway network is very complex. The reasons are the coexistence of two track gauges, two kinds of electrification systems and five types of signaling systems; together with fixed and variable gauge rolling stock, sometimes able to run under different types of electrification and signaling systems. There is even a multiple unit hybrid series (730). The authors have developed a microscopic simulation computer package that calculates timings and minimal paths, and estimates costs, consumptions and emissions. The package is topology-independent and can perform computations for any type of trains. We shall focus here on its use, the structure of its input files and its possibilities.

Peer-review under responsibility of CIT 2014.

Keywords: Railway networks; simulation; consumptions; costs; emissions.

1. Introduction

Planning the operations of *Renfe Operadora* trains on *Adif*'s (Spanish) railway network (Figure 1) is very complex. The reason is that there are:

- two track gauges (there are gauge changeovers installed at certain stations and some three rails sections),

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Peer-review under responsibility of CIT 2014.
doi:10.1016/j.sbspro.2014.12.121

- two kinds of electrification systems (3 KV DC, 25 KV AC, plus 1.5 KV DC in the neighbor France),
- five types of signaling systems (telephone block system, *ASFA, LZB, EBICAB, ERTMS*),
- variable gauge rolling stock, able to run under different types of electrification and signaling systems (and even a series of hybrid multiple units -730).

The authors have developed a microscopic railways simulation computer package that calculates timings and minimal paths, and estimates costs, consumptions and emissions of running trains. The package is denoted *RutasOptiRed* and was developed under the frame of *OptiRed* research project (Anonymous, 2013). It is topology-independent and can perform computations for any type of trains. Details on the formulae used and the underlying algorithms can be found in (Hernando et al., 2012; Roanes-Lozano et al., 2013).

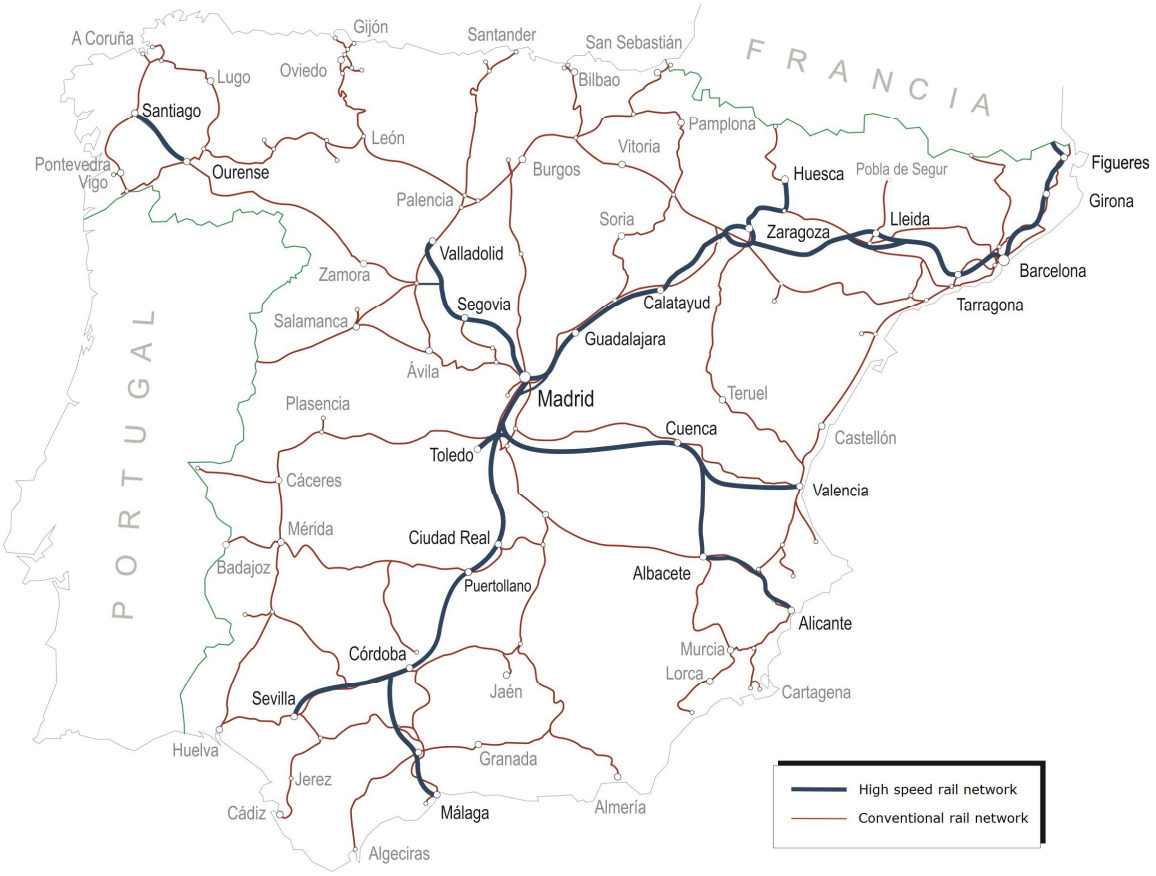

Fig. 1. *Adif*'s railway network at the end of 2013 (Courtesy of the Fundación de los Ferrocarriles Españoles –Spanish Railways Foundation).

We shall focus here on the use of *RutasOptiRed* package, as well as on the structure of its input files and the possibilities of the package. Specific applications to the Madrid-A Coruña and Madrid-Badajoz routes can be found in (Roanes-Lozano et al, 2012a; Roanes-Lozano et al., 2012b), respectively.

Let us underline that *RutasOptiRed* is, essentially, an aid for decision making on rolling stock and route selection. It can also be used to analyze the effect of the characteristics of the infrastructure and the trains in the timings, costs and incomes, consequently allowing optimizing the investments on both of them.

The package is designed to be executed under the most frequently used operative system. It consists of a single file, *RutasOptiRed.exe*, and requires of no installation.

2. Input data files of *RutasOptiRed* package

The package uses four types of input data files, that are obtained saving as *Unicode Text* (*.TXT) the files created with the most frequently used spreadsheet.

2.1. Sections data file

The endpoints of the sections are important stations and junctions. The sections data file (Figure 2) is organized in rows and can have as many rows as necessary, and the following columns:

- Line (alphanumeric string).
- Type of section: A1, A2, B1, C1 (*Adif*, the railway network administrator, has classified the lines and charges *Renfe Operadora*, the train operator company, accordingly).
- Endpoint 1: name, category, existence of gauge changeover, need to reverse the direction.
- Endpoint 2: name, category, existence of gauge changeover, need to reverse the direction.
- Length in km: number.
- Track gauge: Iberian / standard / dual (the latter case is a track with three rails).
- Double track / single track.
- Electrification: 0 / 750 V / 1500 V / 3000 V / 25000 V / dual.
- Signaling: telephone block-system / ASFA / LZB / ERTMS 1 / ERTMS 2.2.2+ / ERTMS 2.3.0.d.
- Slope.
- Maximum speed.
- Average speed for train types N, A, B, C, D (the Spanish rolling stock is classified according to the maximum centrifugal acceleration allowed, what depends on the existence and type of a body tilting system).
- Intermediate stations (distance from Endpoint 1, in km).

Código de línea	Tipo de tramo	Línea	Extremo 1			*Inversiones*
			Nombre	Categoría	Cambiador	
100	C1	Madrid-Hendaya	Madrid Chamartín	e	0	0
100	C1	Madrid-Hendaya	Pitis	e	0	0
100	C1	Madrid-Hendaya	Bif. Principe Pío	b	0	0
100	C1	Madrid-Hendaya	Pinar de las Rozas	e	0	Las Matas Clasificación
100	C1	Madrid-Hendaya	Las Matas	e	0	0
100	C1	Madrid-Hendaya	Villalba	e	0	Segovia
100	C1	Madrid-Hendaya	Ávila	e	0	Peñaranda de Bracamonte
100	C1	Madrid-Hendaya	Arévalo	e	0	0
100	C1	Madrid-Hendaya	Medina del Campo	e	0	0
100	C1	Madrid-Hendaya	Valdestillas	e	0	0
100	C1	Madrid-Hendaya	El Pinar Sur	e	0	0
100	C1	Madrid-Hendaya	El Pinar Norte	e	0	0
100	C1	Madrid-Hendaya	Valladolid Campo Grande	e	0	0

Fig. 2. First columns of the first rows of the sections data file corresponding to *Adif* 's network. This file consists of 764 rows (sections in which the network has been divided) and contains more than 25,000 data.

2.2. Stations data file

The stations data file allows introducing the number of passengers per year, the stopping times specific to some stations, the type of station (for pricing purposes), the population of the city and its income per capita. The package extracts the names of the stations from the sections file, makes a comparison with this list, and alerts the user of any difference.

2.3. Trains characteristics data file

In the trains characteristics data file (Figure 3), each file contains the data of a train type. It can have as many rows as necessary.

Nombre del tren	Ancho	Tipo de tren	Tracción				Compatibilidad				
			Diésel	1500 V CC	3000 v CC	25000 V CA	ASFA	LZB	ERTMS 1	ERTMS 2.2.2+	ERTMS 2.3.0.D
S100	s	a	0	0	1	1	1	1	1	1	0
S102	s	a	0	0	0	1	1	1	1	1	0
S103	s	a	0	0	0	1	1	1	1	1	0
S104	s	a	0	0	0	1	1	1	1	1	0
S112	s	a	0	0	0	1	1	1	1	1	0
S114	s	a	0	0	0	1	1	1	1	1	0
S120	mc	a	0	0	1	1	1	1	1	1	0
S121	mc	a	0	0	1	1	1	0	1	1	0
S130	mtv	a	0	0	1	1	1	1	1	1	0
440	i	a	0	0	1	0	1	0	0	0	0
470	i	a	0	0	1	0	1	0	0	0	0
490	i	a	0	0	1	0	1	0	0	0	0
448	i	a	0	0	1	0	1	0	0	0	0
449	i	a	0	0	1	0	1	0	0	0	0
594	mc	a	1	0	0	0	1	0	0	0	0
596	i	a	1	0	0	0	1	0	0	0	0
598	i	a	1	0	0	0	1	0	0	0	0
S730	mtv	a	1	0	1	1	1	1	1	1	0
334 + 11 coches Talgo VI	i	r	1	0	0	0	1	0	0	0	0
252 + 11 coches Talgo VI	mtv	r	0	0	1	1	1	0	0	0	0
334 + 16 coches Talgo Hotel	i	r	1	0	0	0	1	0	0	0	0
252 + 16 coches Talgo Hotel	mtv	r	0	0	1	1	1	0	0	0	0

Fig.3. *Renfe*'s trains data file (first columns).

The file consists of the following columns:

- Name of the train.
- Gauge (Iberian / Standard / Dual Talgo passengers / Dual Talgo freights / Dual CAF).
- Locomotive hauled or multiple unit.
- Traction: diesel / 750 V / 1500 V / 3000 V / 25000 V.
- Compatibility ASFA / LZB / ERTMS.
- Maximum speed and average speed according to the type: N / A / B / C / D.
- Acceleration type: 1 / 2 / 3 / 4 (trains have been classified in four classes, according to their acceleration).
- Time to cross a gauge changeover.
- Time required to reverse direction.
- Number of seats.
- Fixed cost per seat and rotation minutes.
- Variable cost per time and seat.
- Variable (energetic) cost per km and seat using electric traction.
- Variable (energetic) cost per km and seat using diesel traction.
- Variable cost per km and seat according to the line type.
- Energy consumed per km (electric traction).
- Energy consumed per km (diesel traction).

2.4. Cities data file (names equivalence)

This is an optional file (Figure 4) that allows to define equivalences between the names of the cities and to establish a generic name for all the stations of a city (for example, MADRID*).

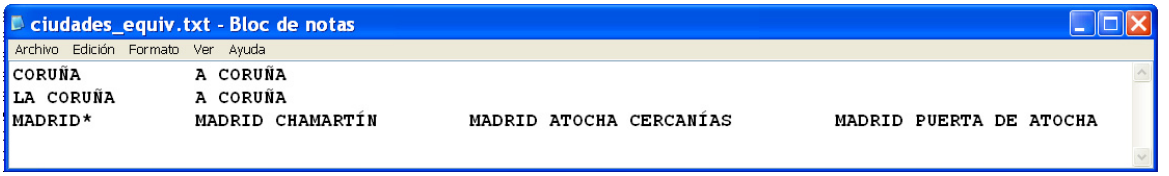

Fig. 4. A file containing information about names of cities.

2.5. Costs parameters data file

This file consists of 11 rows. The first three include the Variable Cost 3 (in cents of Euro per passenger), for each type of station considered (type 1, type 2, type 3). Each of these rows consist of four columns, that contain the cost corresponding (for this type of station) to: journeys exceeding 250 km, between 126 and 250 km, between 90 and 125 km and shorter than 90 km. The rest of the rows are:

- Variable cost 4 (marketing cost, a percentage).
- Overall spending (to be applied to the final cost, in percentage).
- VAT type (percentage).
- CO_2 emissions using diesel traction (kg CO_2/kwh).
- CO_2 emissions using electric traction (kg CO_2/kwh).
- Costs of accidents (Euros/(passenger·km)).
- Value of the time of the passengers (Euros/hour).
- Other external costs of railways (Euros/(passenger·km)).

2.6. Other data

Four more data are introduced directly from the interface: average occupation of seats of trains, design frequency, rotation minutes and ticket price (see Section 4)

3. Data introduction and route calculation

3.1. Direct file loading and route computation

After choosing *Archivo/Abrir Ficheros Red Ferroviaria* (File/Open Railway Network Files) in the initial screen, the data files can be loaded. Then we can choose the train type under *Tren* (Train) or the *Mejor tren* (Best train) in the corresponding drop-down menus (Figure 5).

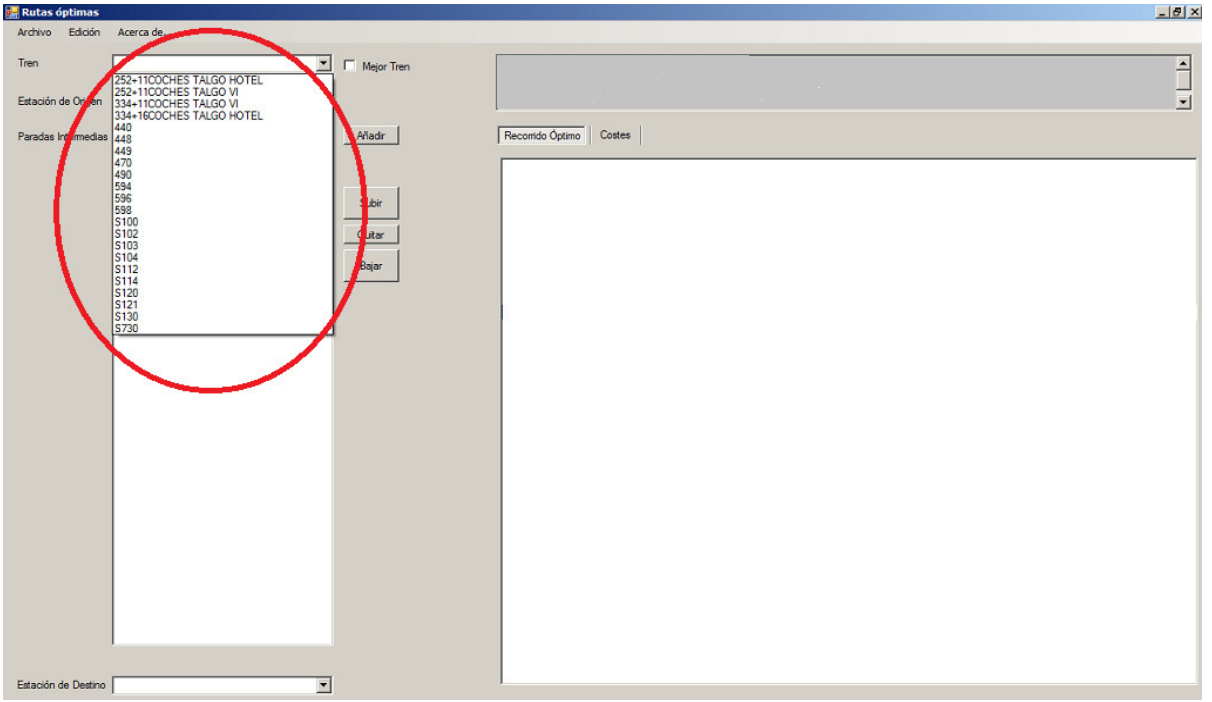

Fig. 5. Train selection.

The drop-down menu *Estación de origen* (Origin station) can be opened afterwards, and the origin station can be chosen. The same can be done with the destination station. As soon as these steps are taken, the timetable of the chosen train for that route shows up (without stops and through the shortest path) (Figure 6).

Intermediate stops are introduced similarly. The user can also force the train to pass through stations without stopping in them. The package automatically detects where the direction has to be reversed and/or gauge changeovers must be crossed (and applies the corresponding time increments).

Timings are computed from the average speeds of the sections and the maximum speeds of the trains. The acceleration and deceleration times are calculated from the difference of speed between sections and the acceleration and deceleration of that type of train (the trains are classified in four groups, according to their acceleration, what is specified at the trains characteristics data file).

An already computed route can be saved in text format (Figure7) and can be copied to a spreadsheet.

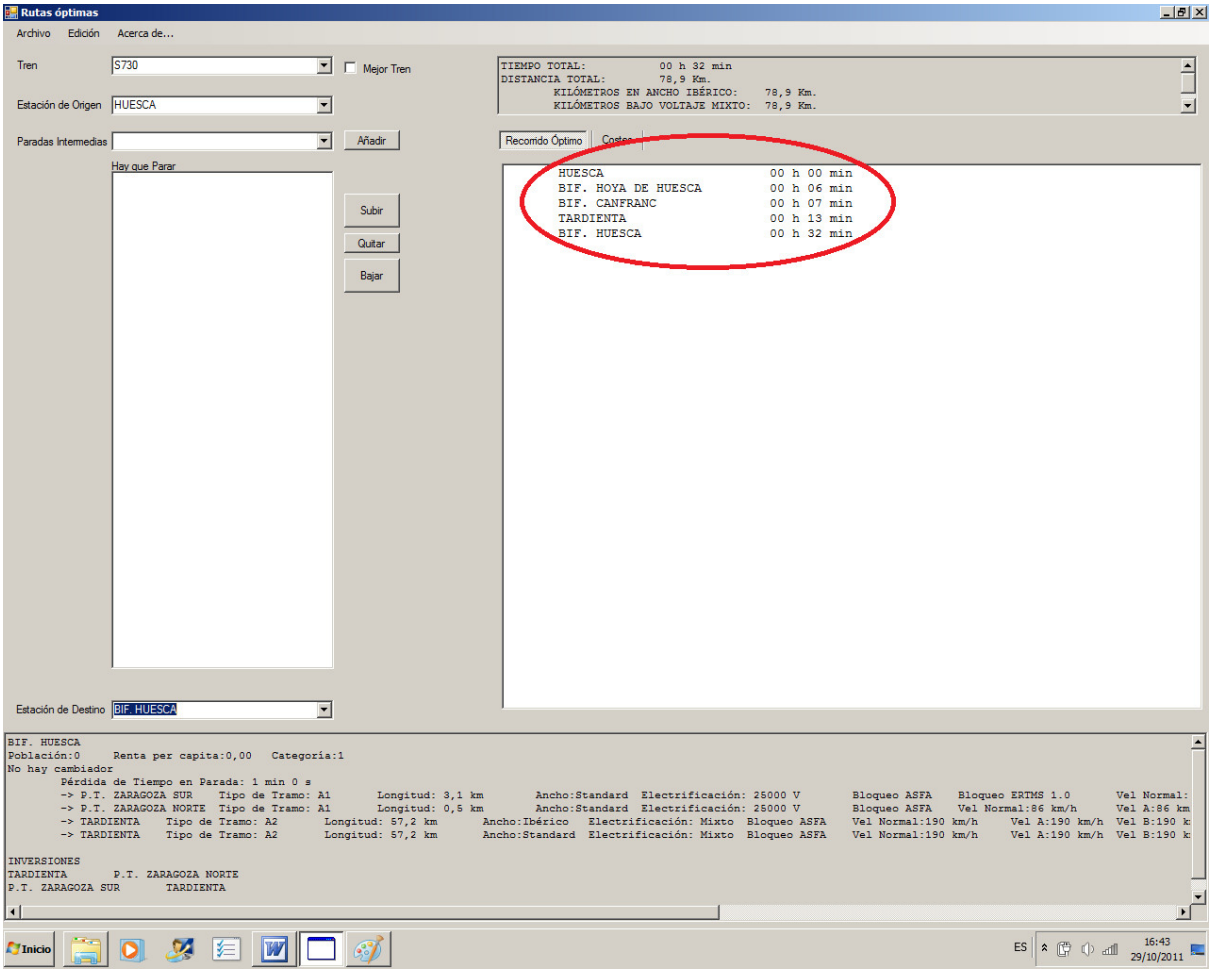

Fig. 6. An already computed route.

3.2. Use of the package using "escenarios" (settings)

Once the data files have been loaded and an optimal route computation has been performed, it is possible to save the corresponding *Escenario* (Settings) by choosing *Archivo/Guardar Escenario* (*File/Save Settings*). This way, loading the different fields and introducing the origin and destination stations and stops can be avoided when working with this route again. To load previously saved settings it is enough to select *Edición/Abrir Ventana de Escenario* (*Edition/Open Settings Window*) and to choose the file name.

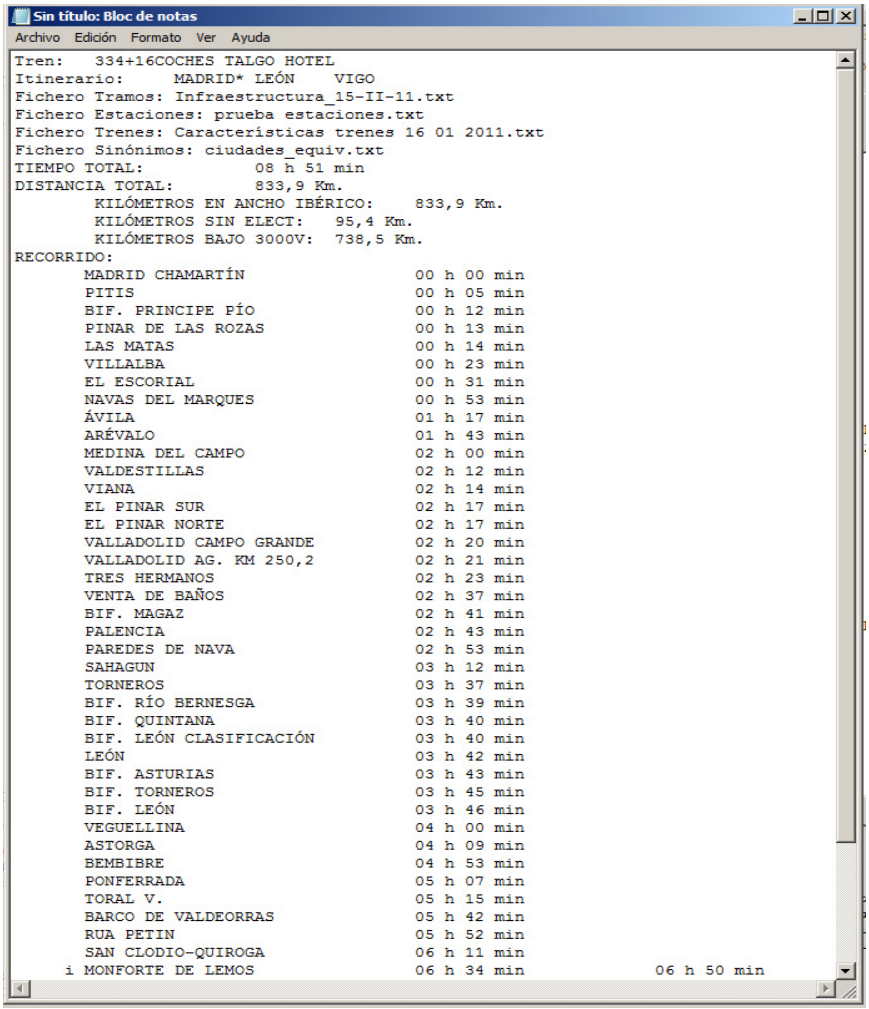

Fig.7. A route saved in text format (partial view).

4. Computing costs, energy and emissions

The package computes minimal routes by default, but it can switch to costs (García-Álvarez, 2010b; García-Álvarez, 2011), energy and emissions computations at any time, by clicking on the *Costes* window tab. Once this is done, the package switches to the window of Figure 8. We can distinguish three zones in it:

- an input data zone, with two window tabs (upper zone, marked with a red border in Figure 8),
- a second zone, regarding the passengers per year (middle zone, marked with a green border in Figure 8),
- a computations zone, with different window tabs (lower zone, marked with a blue border in Figure 8).

The following data can be directly changed in the input data zone of the users interface (Figure 8):

- average occupation of seats of trains,
- design frequency,
- rotation minutes,

- ticket price (in Euros).

In the specific computations zone, the distance covered using electric and diesel engines and through the different line types (expressed in km) is shown. Nevertheless, the other window tabs can be activated (in the following, the data are computed per train, per seat and per passenger):

- time consumed window tab,
- benefits (incomes) and costs window tab,
- energy and emissions window tab: electric energy consumed (in kwh), diesel energy consumed (in kwh), CO_2 emissions (in kg),
- accidents' costs window tab,
- other external costs window tab.

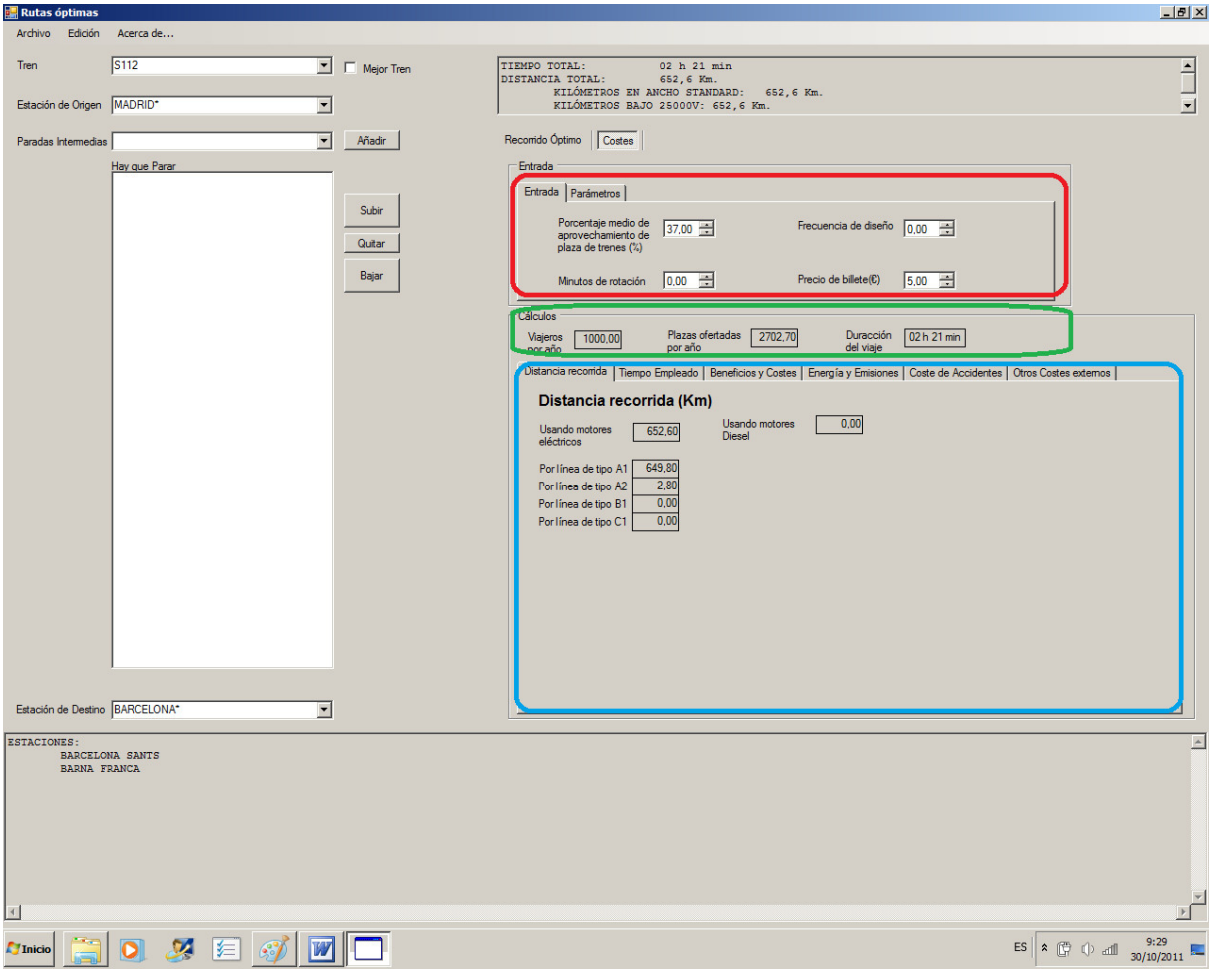

Fig. 8. Possibilities under "Costs, energy and emissions".

5. Conclussions

RutasOptiRed is, essentially, an aid for decision making about the most convenient rolling stock for each line, as it allows analyzing the effect of the characteristics of the infrastructure and the trains in the timings, costs and incomes of the service.

RutasOptiRed also makes possible to optimize investments in infrastructure and trains (quantifying, for example, the hypothetic effect of implementing a partial improvement in some sections of the network, evaluating its effect on the trains passing through those sections or evaluating the use of hybrid trains in a high speed line only partially finished).

The *Fundación de los Ferrocarriles Españoles* is the owner of *RutasOptiRed* package.

Acknowledgements

RutasOptiRed has been partially granted by the research projects: *Ref. 362-2010* (signed between the *Fundación de los Ferrocarriles Españoles* and the *Universidad Complutense de Madrid*), *P116130304* (signed between the *Fundación de los Ferrocarriles Españoles* and the *Universidad Politécnica de Madrid*) and *OptiRed: Desarrollo del marco regulador del transporte de viajeros por ferrocarril en España* (*Gobierno de España*,) (Anonymous, 2013).

We would also like to thank the *Fundación de los Ferrocarriles Españoles* and, specially, its *Gerente del área de I+D+I*, Ángeles Tauler, for their constant support and collaboration.

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