TUTORIAL – SESSION 6
IMPLEMENTATION OF THE VRP PROBLEM
(VEHICLE ROUTING PROBLEM)

SESSION 6: SOLVING MATHEMATICAL MODELS

OPTΣX Mathematical Modeling System

TUTORIAL BASIC

1. **SESSION 1: INTRODUCTION**
   - Introduction to OPTEX (Section 1)
   - OPTEX-EXCEL-MMS (Section 2)
2. **SESSION 2: VRP MODELING IN EXCEL**
   - VRP: Vehicle Routing Problem (Section 3)
   - Implementing VRP Model using EXCEL (Section 4)
3. **SESSION 3: USING EXCEL TO LOAD DATA**
   - Industrial Data Information Systems –IDIS- (Section 5)
4. **SESSION 4: OPTEX-GUI – LOADING MODELS**
   - Loading the Model in OPTEX-MMIS (Section 6)
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6. **SESSION 6: Solving Mathematical Models**
   - Scenarios and Families of Scenarios (Section 9)
   - Solution of Mathematical Problems (Section 10)
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7. **SESSION 7: SQL Servers**
   - Using SQL Servers for IDIS (Section 12)
8. **SESSION 8: Optimization Technologies**
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OPTΣX Mathematical Modeling System

TUTORIAL
IMPLEMENTATION OF THE VRP PROBLEM
(VEHICLE ROUTING PROBLEM)

TUTORIAL
BASIC

6. SESSION 6: Solving Mathematical Models

- Scenarios and Families of Scenarios (Section 9)
- Solution of Mathematical Problems (Section 10)
- Results Information System (Section 11)

SCENARIOS AND FAMILIES OF SCENARIOS

In this moment the modeler has a right model and a set of correct data, therefore, it has a proper environment for "run" the mathematical model with the data stored in the IDIS.

When the user works only with OPTEX-EXCEL-MMS without access OPTEX-GUI, he must consider only the concept of scenario as there is not a way to group the cases, because in EXCEL does not exist the family of scenarios concept, then it is equal to consider a system with family of scenarios that have only one scenario.

OPTEX always meet the specified model for a scenario/case.

SCENARIOS AND FAMILIES OF SCENARIOS

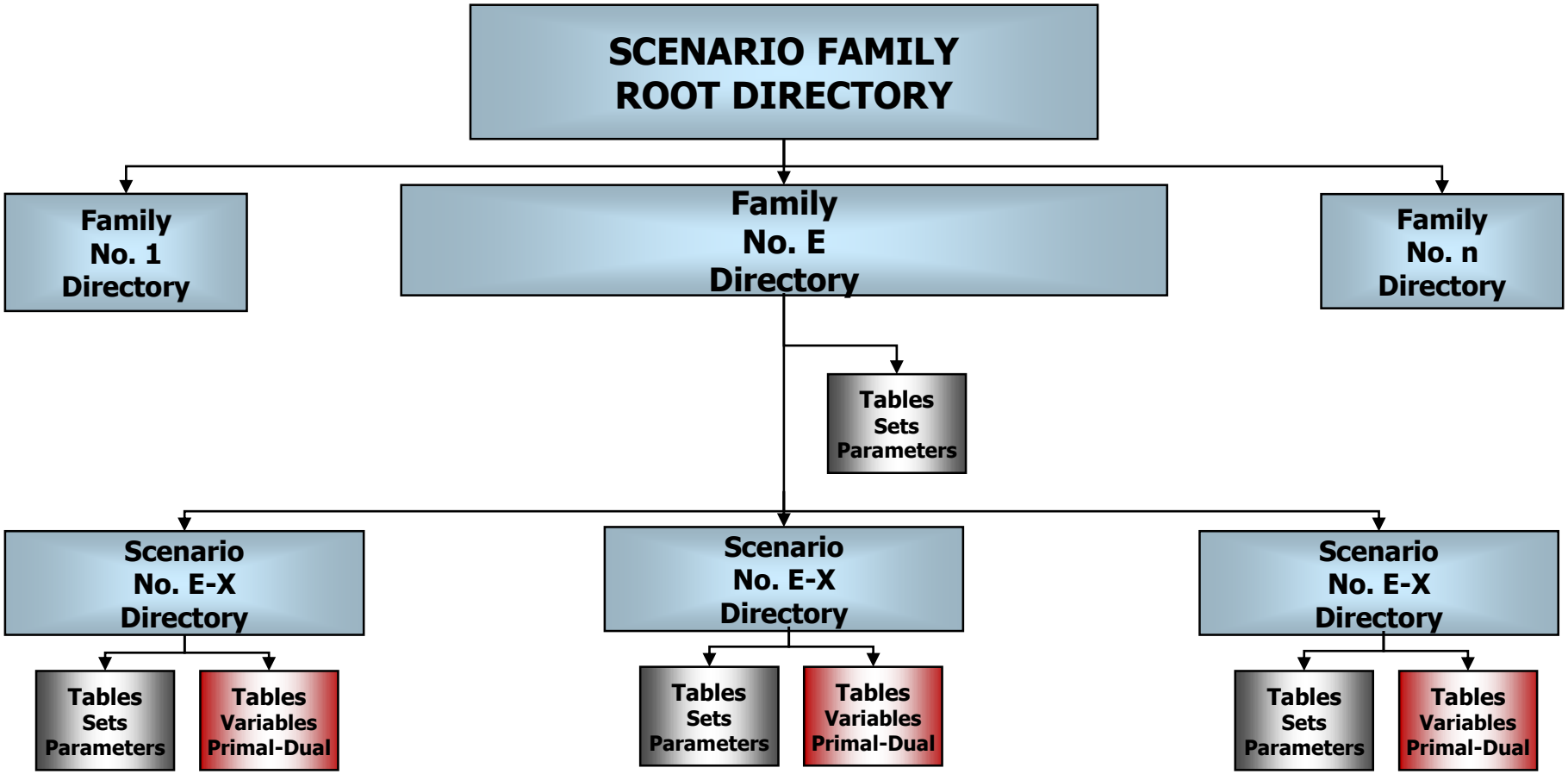
CONCEPTUALIZATION

The concept of Family of Scenarios and Scenarios can group the runs of the mathematical models according to common criteria, deemed appropriate by the user, preferably in mathematical terms that take advantages of this fact; however, this is not needed and families can just be associated with cases that are run using a mathematical model available in the decision support system.

In OPTEX-GUI, a scenario has its own information system. This means that two families of scenarios can have two different information systems, each designed according to the decision supported by the specific model/problem.

The information system of a scenario is divided between the common information for all scenarios that make up the family, and data from each specific scenario. The administrator is responsible for the coordination of integrated information system. The definition of these information systems is make in OPTEX-GUI when the modeler configures the IDIS. The part of the information system that is located in the area of scenarios it is assumed symmetric for all scenarios within a family.

HIERARCHIC INFORMATION SYSTEM FOR MODELS RESULTS



OPTEX AUTOMATICALLY GENERATES A HIERARCHIC INFORMATION SYSTEM TO STORE THE RESULTS OF THE MODELS USING THE CONCEPTS OF SCENARIOS AND FAMILY OF SCENARIOS.

SCENARIOS AND FAMILIES OF SCENARIOS

DEFINITION

The first step to define a family of scenarios, or a scenario, is to have clear the mathematical model and the objective function to use, that delimit the problem that modeler wish to associate with the family; to do this the user must determine:

- **ID/Code: Code given to the scenario family, or to the scenario. This code will be used by OPTEX for the location data-tables as it determines the directory that is located from the root directory of scenarios.**
- **Description**
- **Model ID: mathematical model associated**
- **Planning Horizon ID: the planning horizon associated with the scenarios family. It is required to discrete time models.**
- **Objective Function: objective function ID**
- **Type of Optimization: maximize, minimize, minimax or maximin.**
- **Start Date: date for which time is considered zero. (t = 0). Valid for models with discrete time periods.**
- **Start Time: Start time for time zero. (t = 0)**

SCENARIOS AND FAMILIES OF SCENARIOS

DEFINITION

To parameterize families of scenarios at OPTEX-GUI it is required to access the window of Families of Scenarios that includes tools that are activated with the right click of the mouse:

- **Automatically create the tables needed for the family of scenarios, and**
- **Enable the control window OPTEX-EXE**

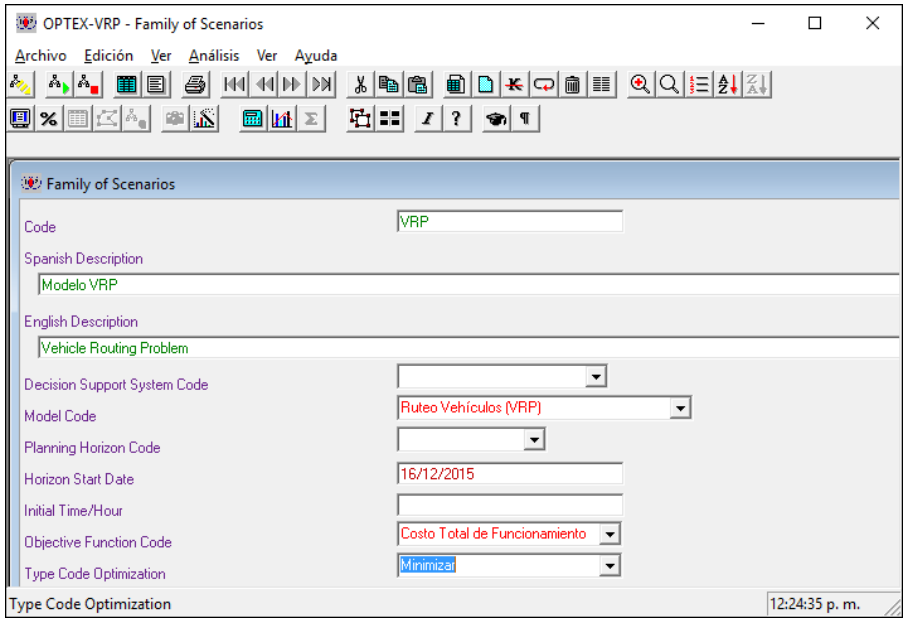
In the case of the VRP to define a family of scenarios, or scenario, it should be specifying:

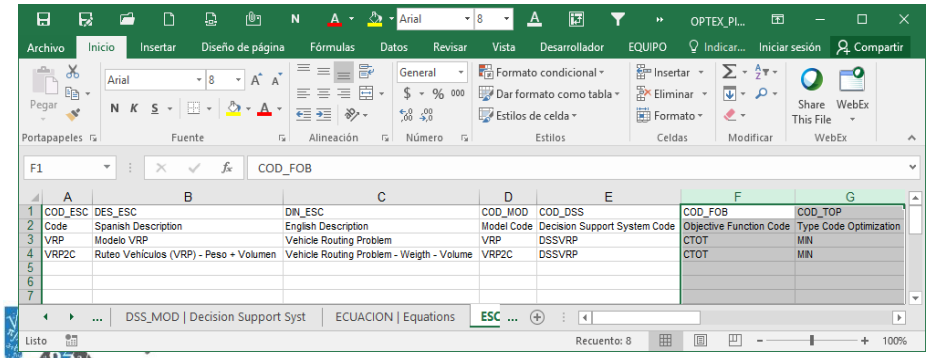
- **Mathematical Model**
- **Objective Function**
- **Scenario Control Tables; tables ESC_xxx where xxx is associated with the physical entity of the information system. In this case VEH, NOD, CAJ and PED.**

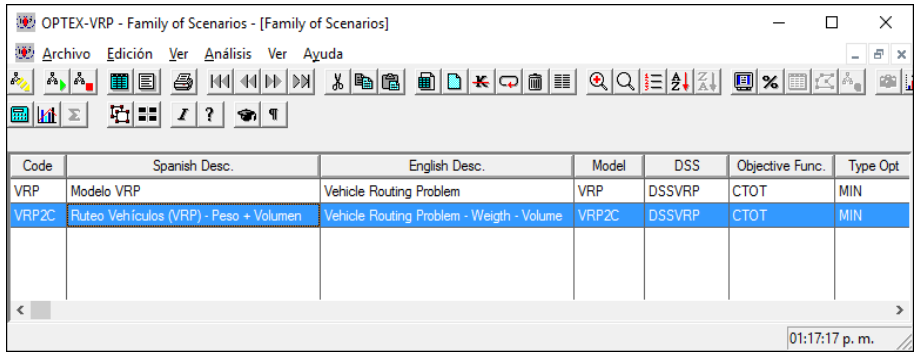
SCENARIOS AND FAMILIES OF SCENARIOS

DEFINITION

The following figure shows the definition of two families of scenarios (scenarios in case OPTEX-EXCEL-MMS).





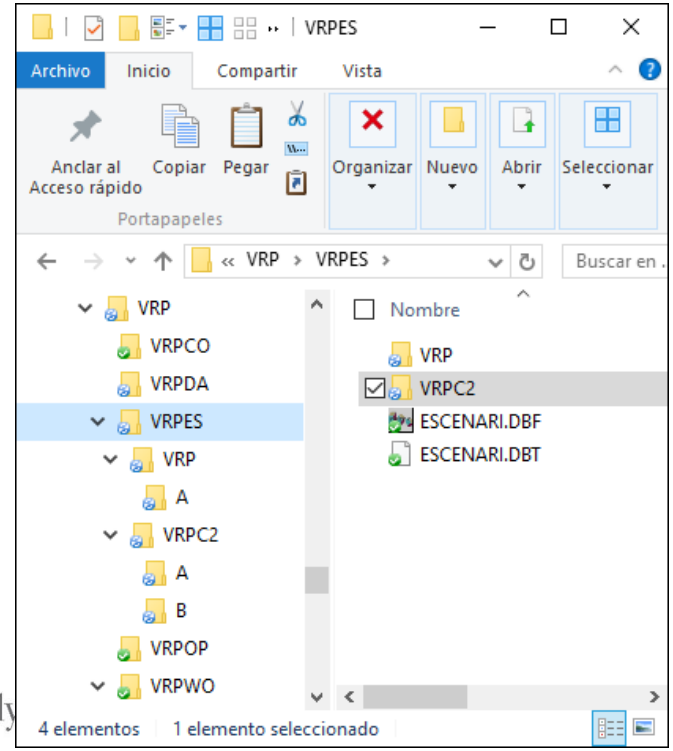


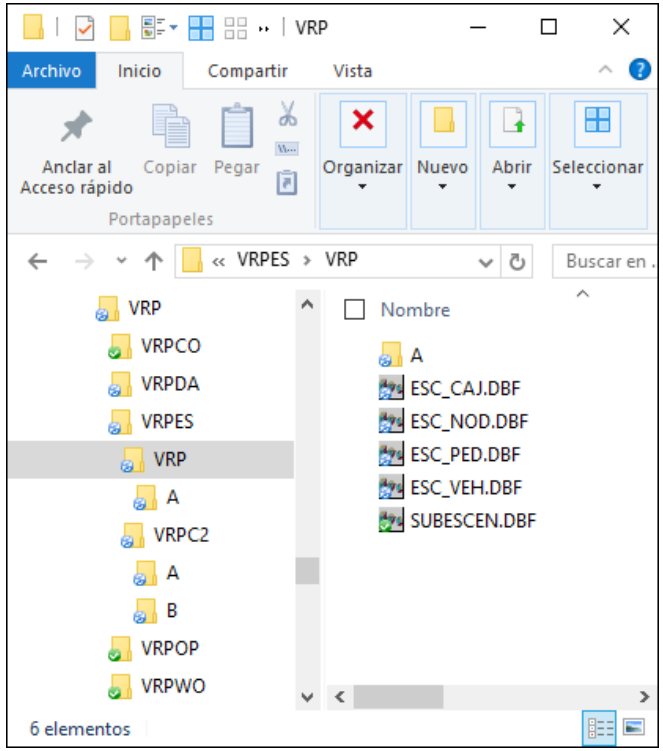
SCENARIOS AND FAMILIES OF SCENARIOS

SCENARIO TABLES : LOCATION

The first step in locating tables that define the configuration of industrial database, which will consider the mathematical models, is related to the understanding of the possible locations of the tables within the areas of the application. In the images that are presented below are designed two families of scenarios, VRP (with a scenario A) and VRPC2 (with a scenario A and one B); families scenarios differ in the mathematical models, VRP and VRPC2.

In the root directory of the families of scenarios (VRPES) must be located ESCENARI table containing the families of scenarios and in the root directory of each scenario family SUBESCEN must locate the table containing the family scenario.





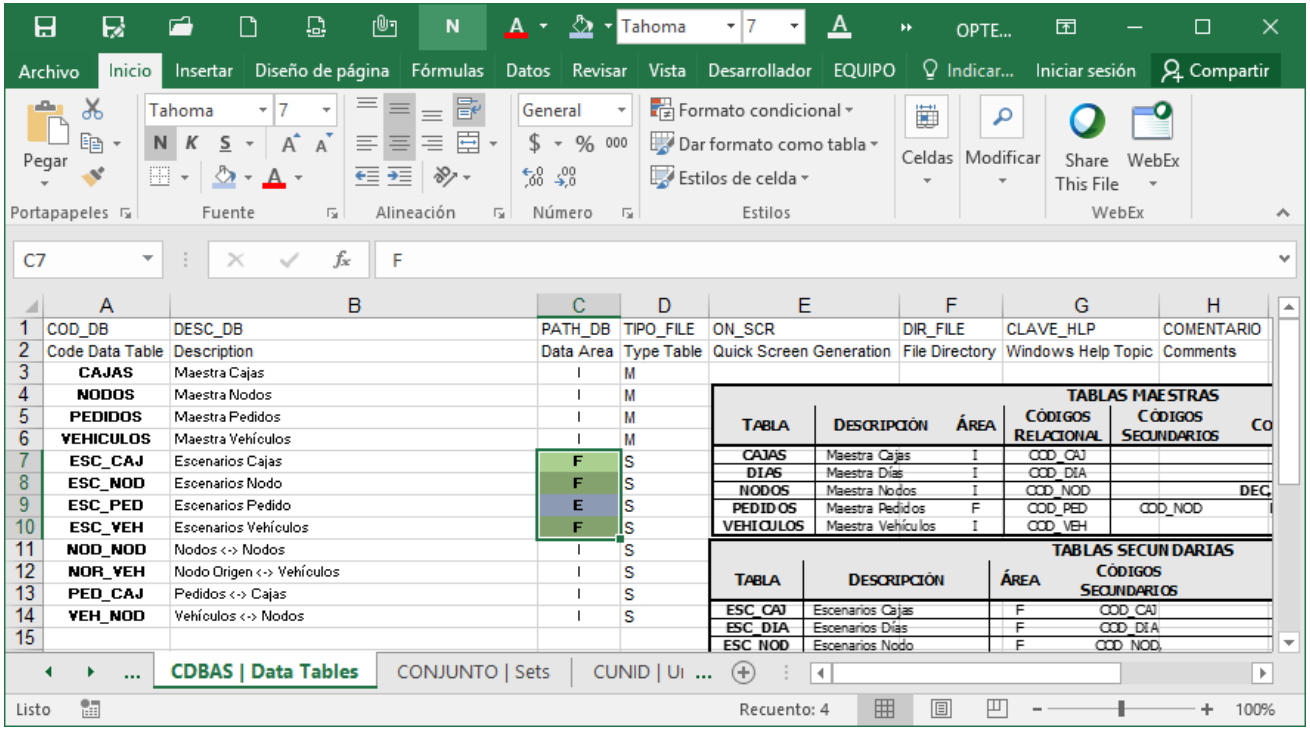
SCENARIOS AND FAMILIES OF SCENARIOS

SCENARIO TABLES : LOCATION

The configuration of the family is to define its topology, means, those entities of IDIS to be included in the mathematical model, which define the relationships between entities that will be taken into account. "Normally", to do this a set of tables at the level of the family of scenarios is defined.

In this case, scenarios are differentiated by the number of vehicles, orders, customers and boxes involved in the scenario. For this reason, the scenario tables are relocated in the in the root of the families of scenarios (ESC_VEH, ESC_CLI and ESC_CAJ) and (ESC_PED) in the scenario. It should be noted that the subset of physical entities in the scenarios must comply with the rules of integrity of the information system.

The following figure presents in EXCEL table CDBAS with the new locations.



	A	B	C	D	E	F	G	H
1	COD_DB	DESC_DB	PATH_DB	TIPO_FILE	ON_SCR	DIR_FILE	CLAVE_HLP	COMENTARIO
2	Code Data Table	Description	Data Area	Type Table	Quick Screen Generation	File Directory	Windows Help Topic	Comments
3	CAJAS	Maestra Cajas	I	M				
4	NODOS	Maestra Nodos	I	M				
5	PEDIDOS	Maestra Pedidos	I	M				
6	VEHICULOS	Maestra Vehículos	I	M				
7	ESC_CAJ	Escenarios Cajas	F	S				
8	ESC_NOD	Escenarios Nodo	F	S				
9	ESC_PED	Escenarios Pedido	E	S				
10	ESC_VEH	Escenarios Vehículos	F	S				
11	NOD_NOD	Nodos <-> Nodos	I	S				
12	NOR_VEH	Nodo Origen <-> Vehículos	I	S				
13	PED_CAJ	Pedidos <-> Cajas	I	S				
14	VEH_NOD	Vehículos <-> Nodos	I	S				
15								

TABLAS MAESTRAS

TABLA	DESCRIPCIÓN	ÁREA	CÓDIGOS RELACIONAL	CÓDIGOS SECUNDARIOS	CO
CAJAS	Maestra Cajas	I	COD_CAJ		
DIAS	Maestra Días	I	COD_DIA		
NODOS	Maestra Nodos	I	COD_NOD		DEC
PEDIDOS	Maestra Pedidos	F	COD_PED	COD_NOD	
VEHICULOS	Maestra Vehículos	I	COD_VEH		

TABLAS SECUNDARIAS

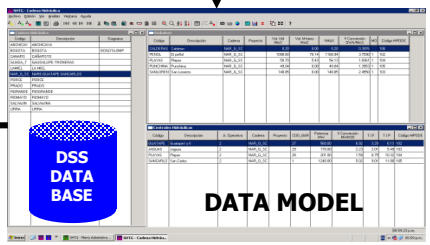
TABLA	DESCRIPCIÓN	ÁREA	CÓDIGOS SECUNDARIOS
ESC_CAJ	Escenarios Cajas	F	COD_CAJ
ESC_DIA	Escenarios Días	F	COD_DIA
ESC_NOD	Escenarios Nodo	F	COD_NOD

SOLUTION OF THE MATHEMATICAL MODELS

SOLUTION VIA REMOTE OPTEX-WEB

SOLUTION OF THE MATHEMATICAL MODELS

SOLUTION VIA OPTEX-EXCEL-MMS



DATA MODEL

ALGEBRAIC MODEL

$$Min \quad \Psi = \sum_{t=1}^{T} \sum_{i=1}^{N_E} \Psi_{(i,t)}$$

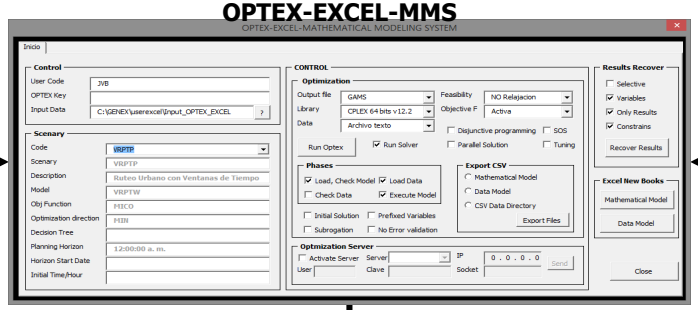
s.a.

$$\Psi_{(i,t)} = \frac{c_{(i,t)}}{2} \cdot P_{(i,t)}^{\ 2} + e_{(i,t)} \cdot P_{(i,t)}$$

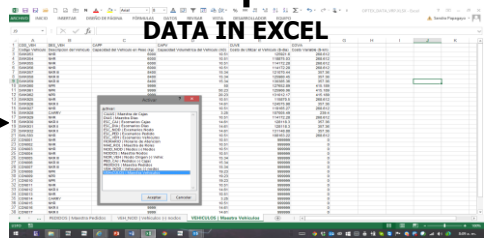
$$V_{(j,t+1)} = V_{(j,t)} + \tau \cdot \left(\mathcal{A}_{(j,t)} - \mathcal{Q}_{(j,t)} - S_{(j,t)} \right)$$

$$P_{(j,t)} = \rho_{(j)} \cdot \mathcal{Q}_{(j,t)}$$

OPTEX-EXCEL-MMS



DATA IN EXCEL

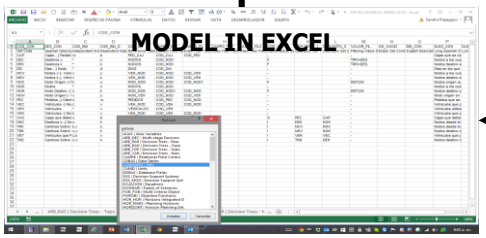


optexmodel.opx

*.CSV FILES

FILLING THE BLANKS

MODEL IN EXCEL

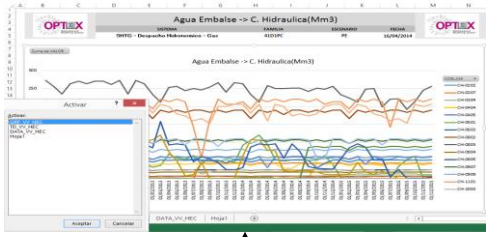


CODE GENERATION

OPTIMIZATION TECHNOLOGY

C++ GAMS ILOG An IBM Company OPL FICO™ MOSEL AIMMS AMPL

OPTEX-EXCEL-GUI



PRIMAL – DUAL VARIABLES

SOLUTION OF THE MATHEMATICAL MODELS

SOLUTION VIA OPTEX-EXCEL-MMS

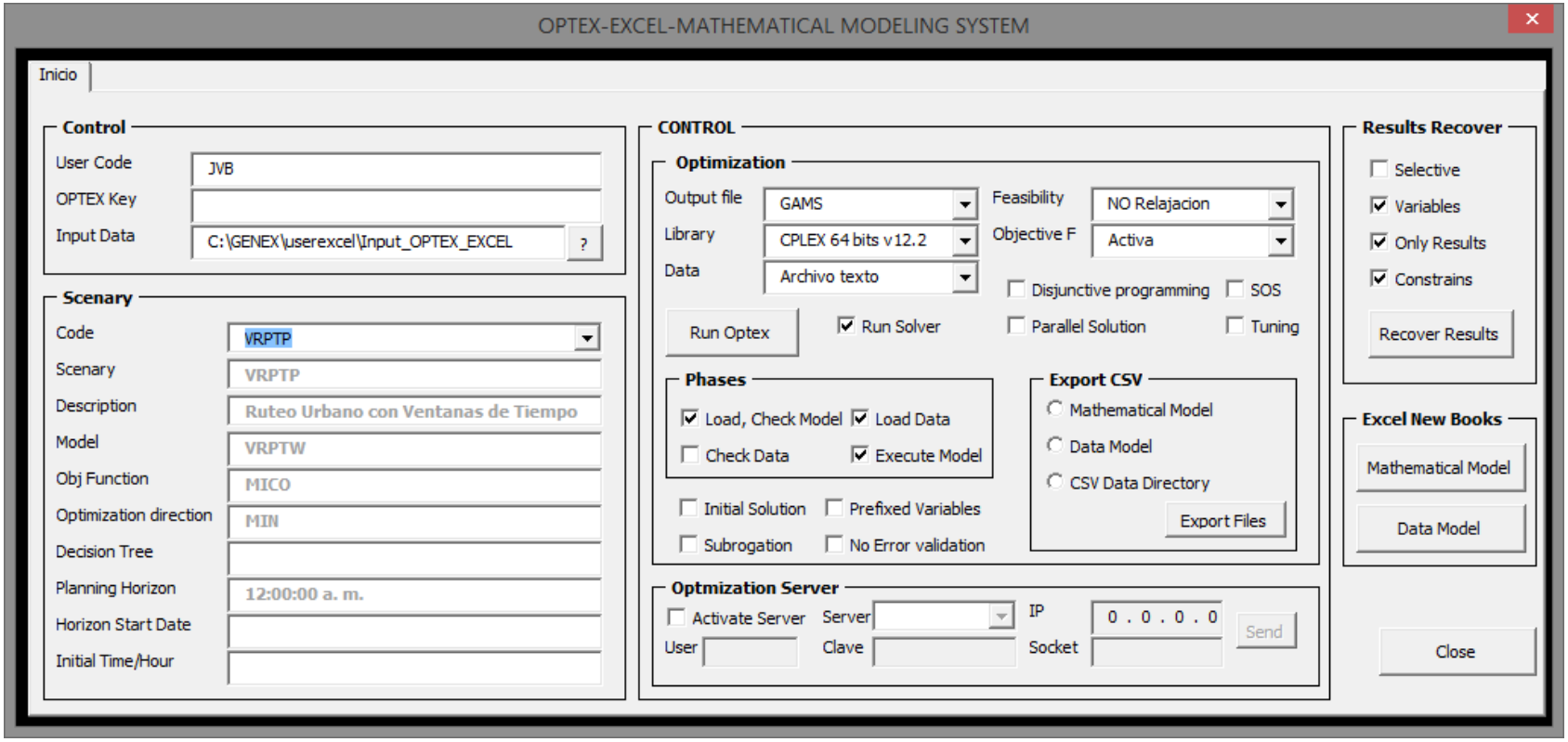
OPTEX-EXCEL-MMS is an application developed in Visual Basic using EXCEL functionality.

OPTEX-EXCEL-MMS collects two files in EXCEL, the first mathematical models (MMIS) and the second the input data (IDIS), and generates CSV files for each sheet of EXCEL workbooks and generates the OPTEX initialization file (optexmodel.opx) that defines the process to be performed, which is oriented to generate a code in a particular technology optimization and use it to solve the mathematical problems that are part of the model.

SOLUTION OF THE MATHEMATICAL MODELS

SOLUTION VIA OPTEX-EXCEL-MMS

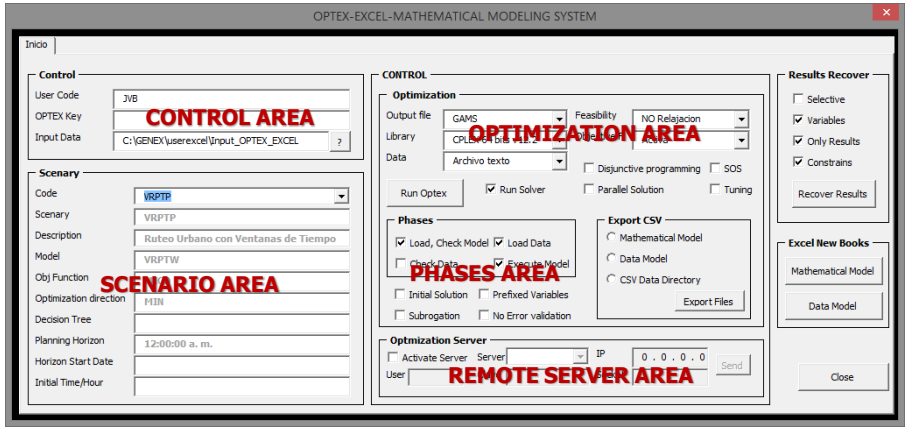
Upon entering the OPTEX-EXCEL-MMS application the next screen, that integrates several areas related to control of OPTEX, is observed.



SOLUTION OF THE MATHEMATICAL MODELS

SOLUTION VIA OPTEX-EXCEL-MMS

- **Control Area** in which the user must enter its data and select the folder (directory) containing the CSV files, for the mathematical model and the data model.
- **Optimization Area** allows to select the options that are used to solve the mathematical model, the main selection is related to the optimization platform to use.
- **Phases Area** is part of the optimization area and lets to select what actions will perform OPTEX. These possibilities have already been described previously and determine whether:
  - Load and check the model
  - Load industrial data and if the data integrity is verified
  - Run the program that solves the mathematical model
- **Scenario Area** that allows the user to characterize and select the scenario and the model that will solve by OPTEX. These options are taken from the ESCENARI.csv table that must be included in the selected directory.
- **Remote Server Area** contains the data of the remote server on which the problem will be solved, when the user uses this option.



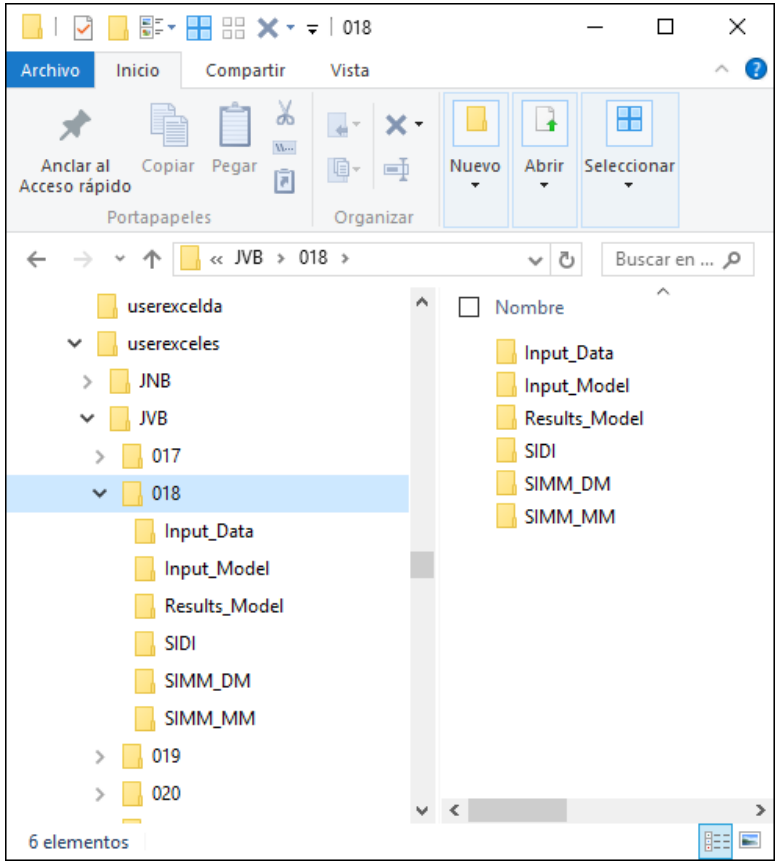
Annex A contains the component installation procedure to be followed by the user to control the execution of OPTEX-EXCEL-MMS on a remote server OPTEX.

SOLUTION OF THE MATHEMATICAL MODELS

SOLUTION VIA OPTEX-EXCEL-MMS

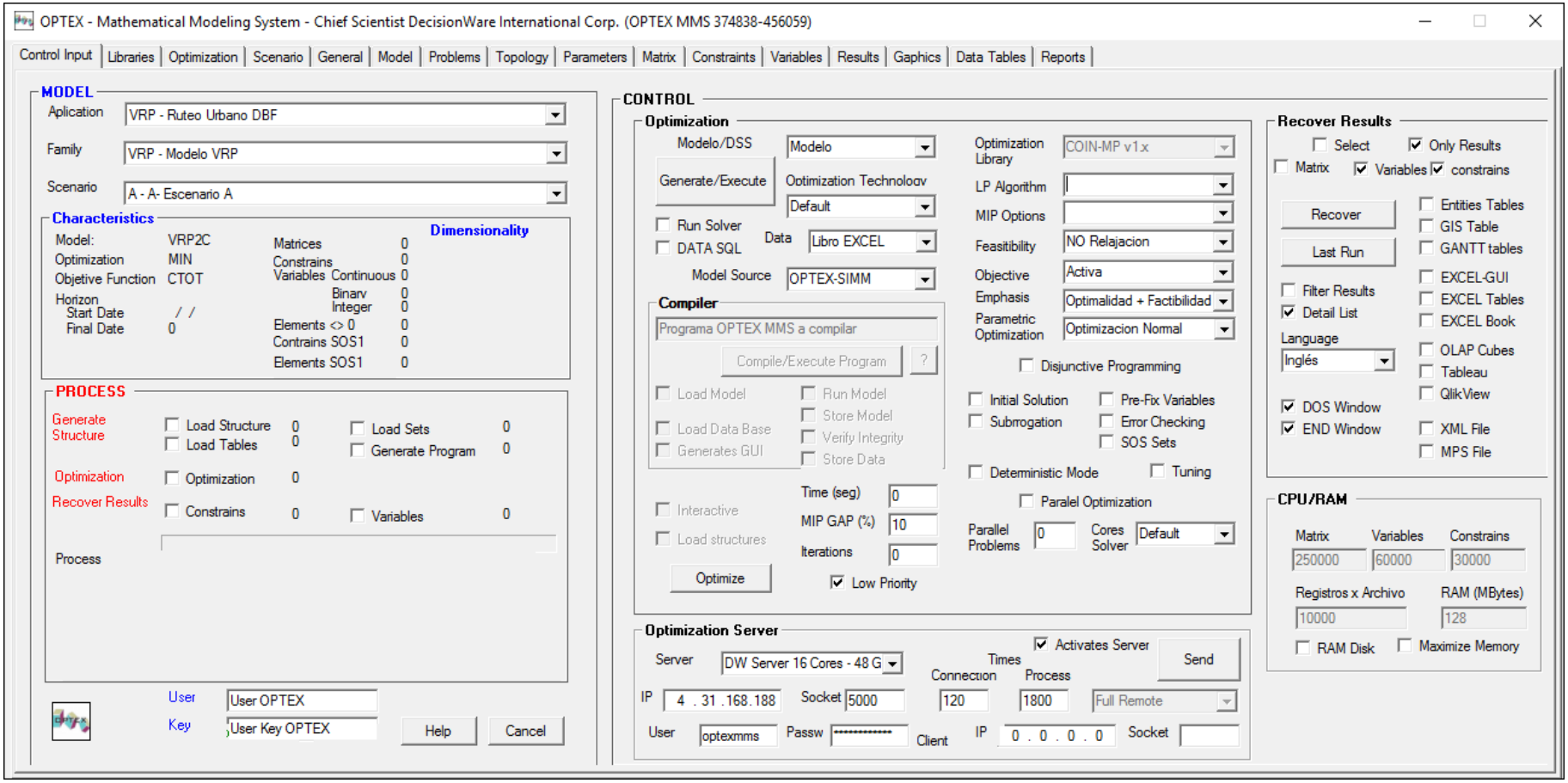
The results of the process are stored in a directory nnn (a numerical code assigned by OPTEX, considering user code) which contains six (6) subdirectories with the following contents.

- **Input_Model:** CSV files used to load the mathematical model and the data model of the application
- **Input_Data:** CSV files used to load industrial data to the data tables described in the data model of the application.
- **Input_Model:** CSV files used to load the mathematical model and the data model of the application.
- **IDIS:** DBF format tables that contain the data used to solve the mathematical model
- **MMIS_MM:** tables in DBF format containing the formulation of the mathematical model.
- **MMIS_DM:** tables in DBF format containing the structure of IDIS data model IDIS and all tables that are required to handle the user interface using OPTEX-GUI.
- **Results_Model:** OPTEX processing results, include all the files used as input to computer programs and mathematical models and results tables in CSV format. The results are the same as those obtained when the OPTEX-EXE is used.



SOLUTION OF THE MATHEMATICAL MODELS

SOLUTION VIA OPTEX-EXE



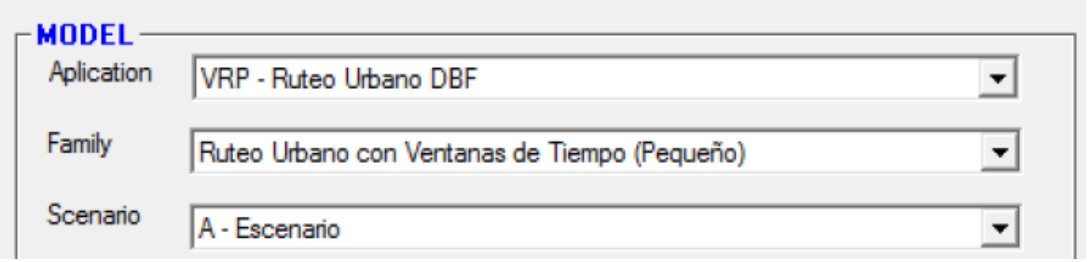
Control is exercised defining parameters that are placed in various areas which are described in detail in the Manual OPTEX User; then, the window is partially presented:

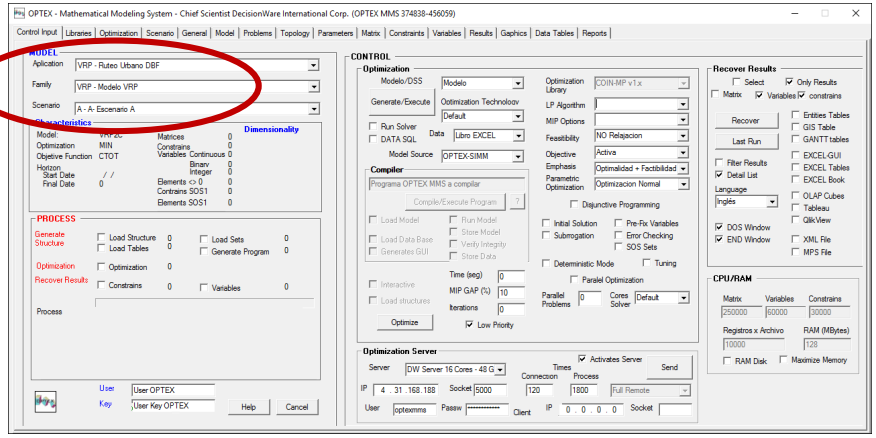
SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - MODEL AREA

Oriented selection of the case to be solved, the user must select:

- **OPTEX Application**
- **Scenario Family**
- **Sscenario**





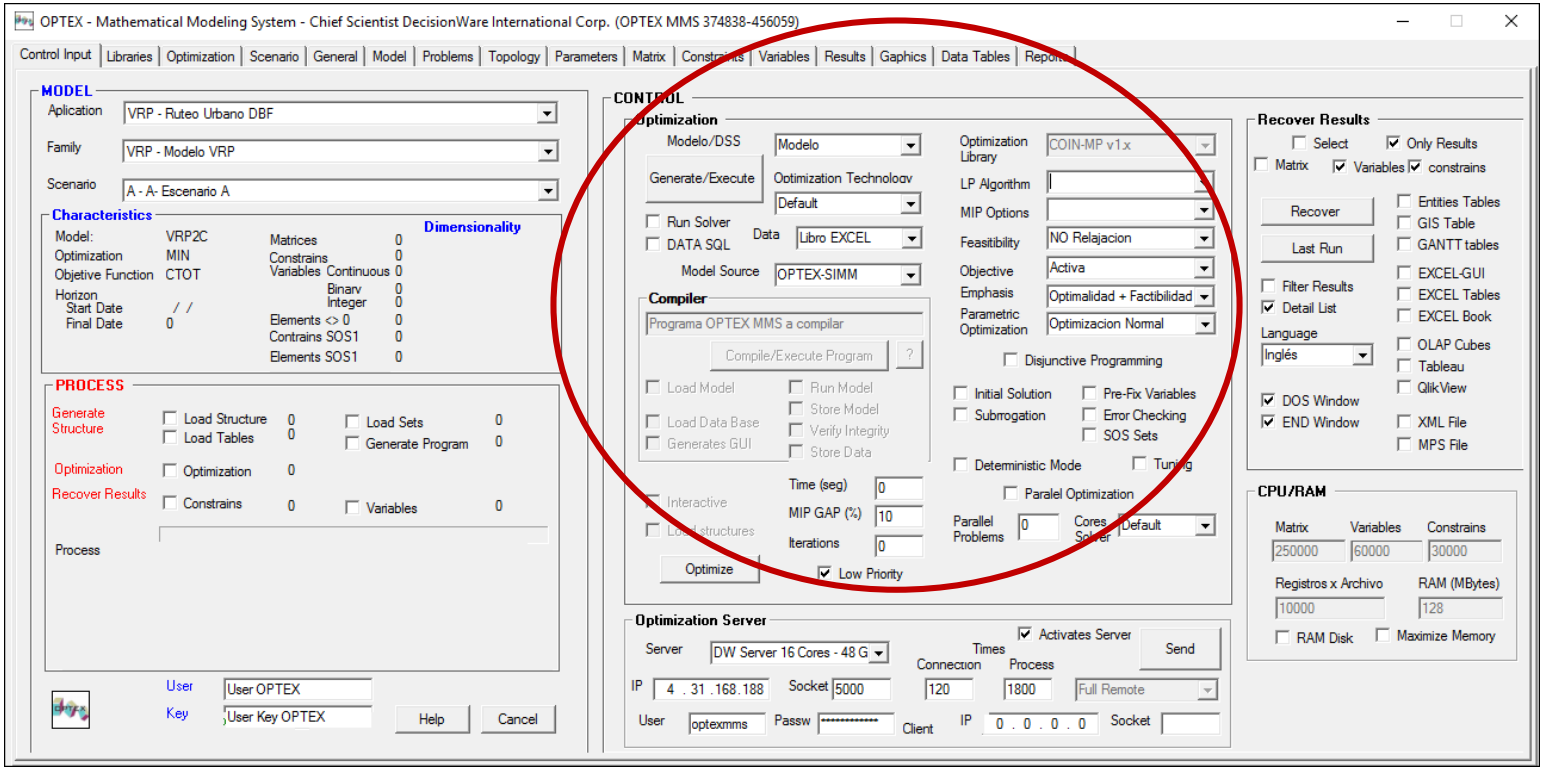
SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - CONTROL AREA

Oriented to specify the actions, and the setting of such actions, under which will operate OPTEX-EXE.

It consists of several sub-areas.

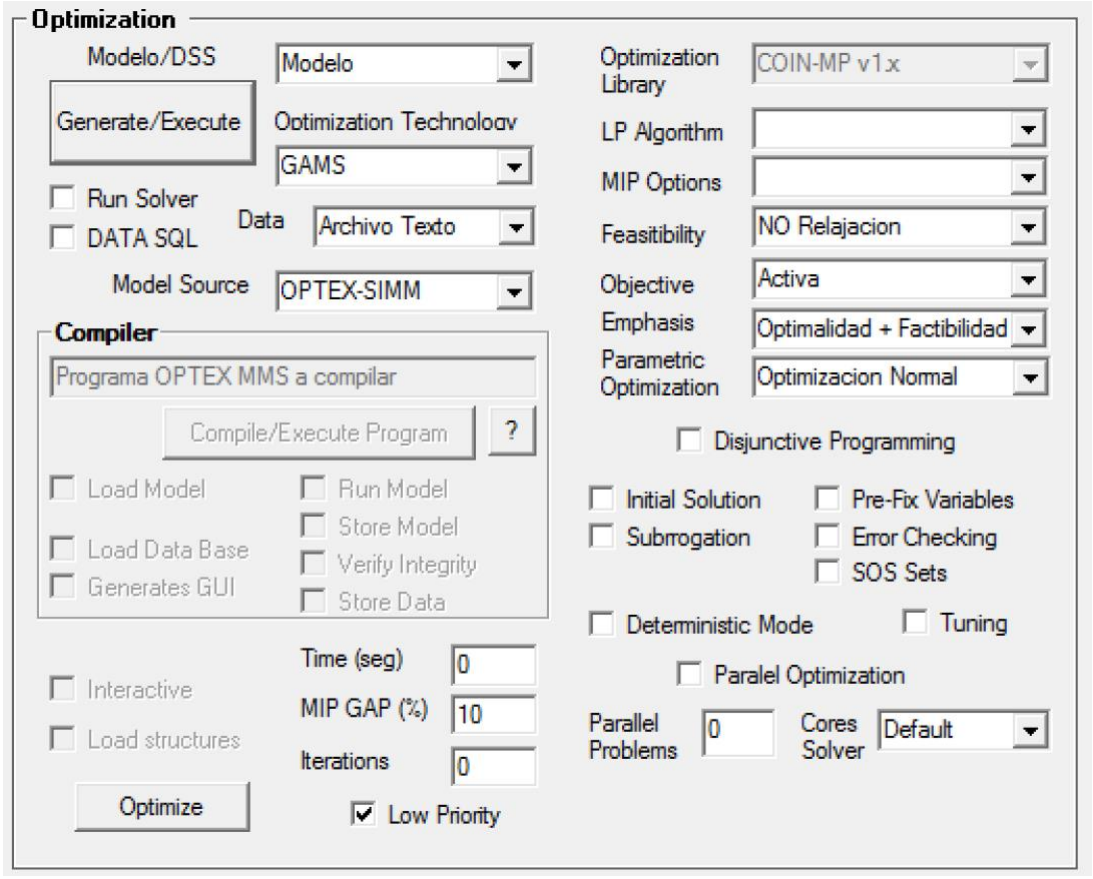
- **Optimization**
- **Data Recovery**
- **Optimization Server**
- **CPU/RAM**



SOLUTION OF THE MATHEMATICAL MODELS

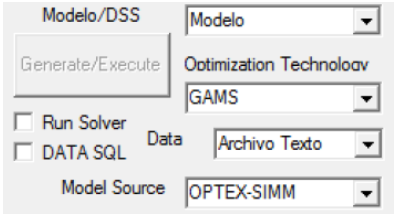
OPTEX-EXE - OPTIMIZATION SUB-AREA

Oriented to specify the parameters to be considered when performing the optimization. It is organized by several "sub-sections" related to different aspects of the process.



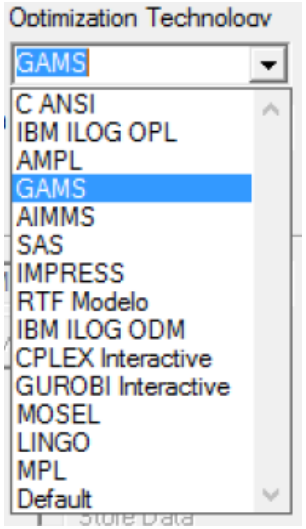
SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - OPTIMIZATION TECHNOLOGY SECTION



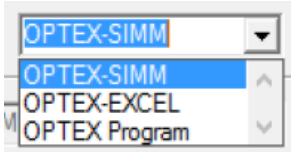
Model/DSS: **Specifies whether the process is related with a model or with a set of models that integrate a DSS.**

Optimization Technology: **Specifies the type of program to be generated. The options available depend of the type of license that the user has and on the technologies that have installed his PC or in the OPTEX-OPTIMIZATION-SERVER.**



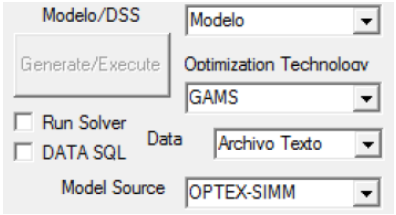
Source Model: **Determines the source of the mathematical model. The options are:**

- **OPTEX-MMIS**
- **OPTEX-EXCEL.MMS**
- **OPTEX Program**



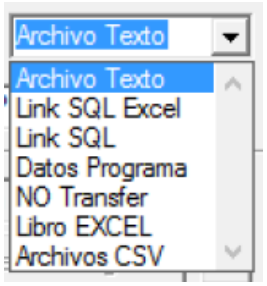
SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - OPTIMIZATION TECHNOLOGY SECTION



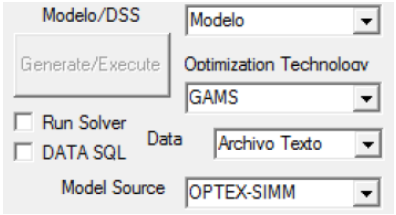
Data Source: determines the data source to be used for optimization. The options are:

- **Text File:** Data tables, DBF or SQL, will become text files.
- **Link EXCEL SQL:** Data is read from a book EXCEL using an ODBC link type (used in GAMS).
- **SQL Link:** Data is read from server using an ODBC associated to the application.
- **Program Data:** Data tables, DBF or SQL are included as part of the generated program (when it applied).
- **NO Transfer:** No file transfer process is performed.
- **EXCEL Book:** The data is in an Excel workbook type OPTEX (XML) located in the directory associated with the scenario.
- **CSV files:** The data is in CSV files located in the directory associated with the scenario.



SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - OPTIMIZATION TECHNOLOGY SECTION



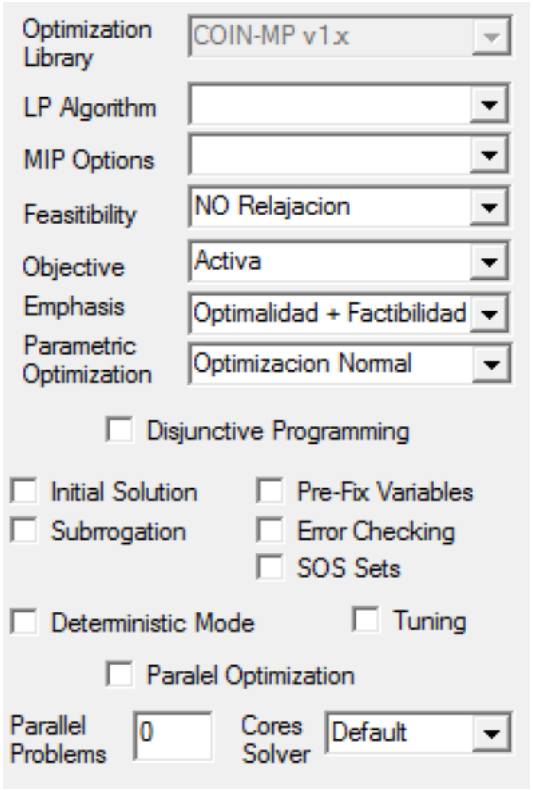
Run Solver: Activates the process of solving the mathematical model. If unchecked, the process stops and ends by opening the IDE (Integrated Development Environment) interface of the selected optimization technology.

DATA SQL: Indicates that the data collection should access a SQL data source type, using an ODBC that the user specified during the optimization process

Generate/Execute: Button that activates the process of generating and executing the process associated with the model/DSS.

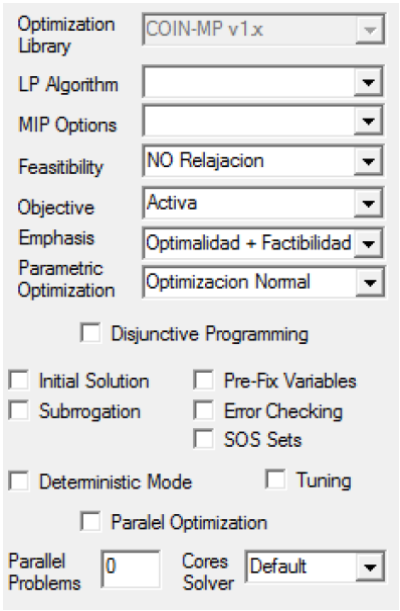
SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - PARAMETER OPTIMIZATION SECTION

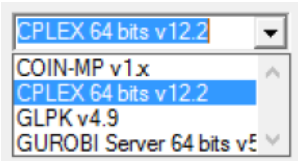


SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - PARAMETER OPTIMIZATION SECTION



Optimization Library: **With programs in C ANSI, it indicates the optimization library that must use OPTEX-EXE.**

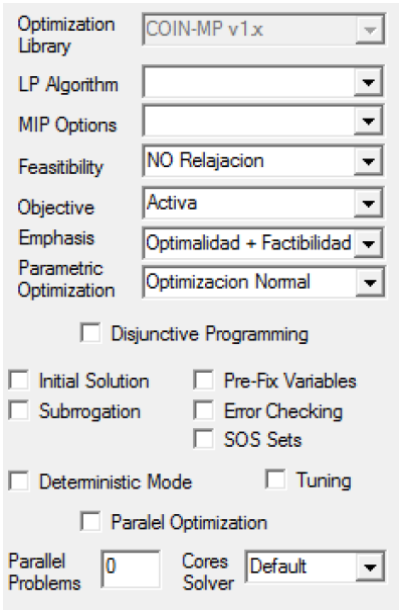


LP Algorithm: **Not used**

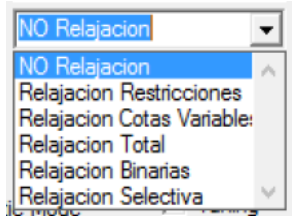
MIP Options: **Not used**

SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - PARAMETER OPTIMIZATION SECTION



Feasibility: **Allows relax the constraints model to analyze the feasibility. Four options considered:**

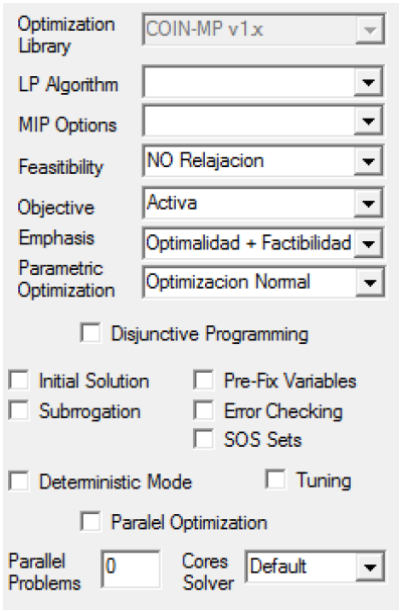


- **NO Relaxation:** **it is the normal option, in which all functional and variable bounds of constraints are active.**
- **Constraints Relaxation:** **Indicates that all functional constraints must be relaxed, including artificial variables with "infinite" cost in the objective function; so as to detect constraints that present feasibility problems.**
- **Relaxation Bounds Variables:** **Indicates that all bounds of the relaxed variables must be relaxed, including artificial variables with infinite cost in the objective function, so as to detect bounds of the variables that present feasibility problems.**
- **Total Relaxation:** **Indicates relaxation of all functional constraints and all bounds of the variables.**
- **Selective Relaxation:** **being implemented.**

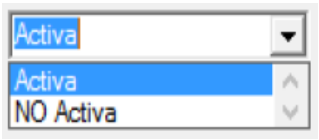
The results of the violation of the constraints are included in the VV_vvv.opt and RR_rrr.opt tables in the ERROR field.

SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - PARAMETER OPTIMIZATION SECTION



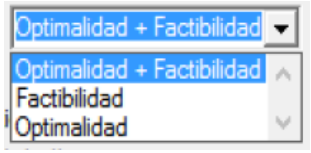
Objective Function: Activate or ignore the purpose of the model function. Two possibilities are considered:



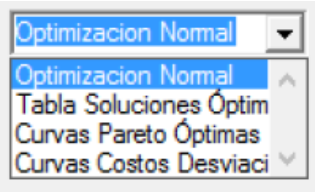
- **Active:** it corresponds to the normal option, which is considered the defined target for the model function. When the options of feasibility are activated implemented, OPTEX optimization process involves two phases: first, the feasibility is minimized and subsequently, if the problem is feasible, the user given objective function is optimized.

- **NO Active:** Indicates that the objective function of the model is ignored. This parameter must be used when required to analyze the feasibility of the problem alone.

Emphasis: indicates the type of emphasis used in the optimization process

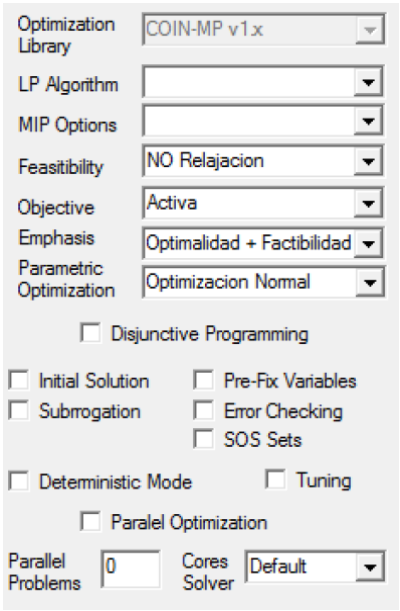


Parametric Optimization:



SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - PARAMETER OPTIMIZATION SECTION



Disjunctive Programming: Indicates that the binary model is formulated to be resolved in accordance with the principles of the Disjunctive Programming (Grossmann, I. [1]). It is implemented for GAMS and C using CPLEX solver.

Initial Solution: Indicates that initial starting must be included in the process. This solution must be a result of a previous run.

Subrogation: Not used

Preset Variables: Indicates that fixed values for the variables must consider in the optimization process.

Error Checking: Indicates that, during the optimization process, or at the end, information relevant to validation errors should be generated for sets and parameters

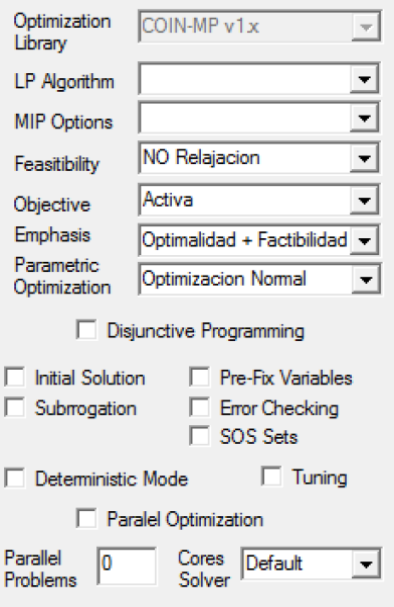
SOS: It depends on the solver and indicates that the binary model should be solved including constraints SOS (Special Ordered Sets) type.

Deterministic Mode: Included in the solution process the instructions necessary for the mathematical models are solved in deterministic mode; the alternative is opportunistic.

Tuning: Enables the option of tuning algorithms if it is available. It depends on the optimization technology used.

SOLUTION OF THE MATHEMATICAL MODELS

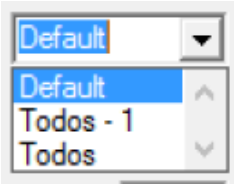
OPTEX-EXE - PARAMETER OPTIMIZATION SECTION



Parallel Optimization: **Indicates that the generated code should include the option of parallel for multi-problem optimization models.**

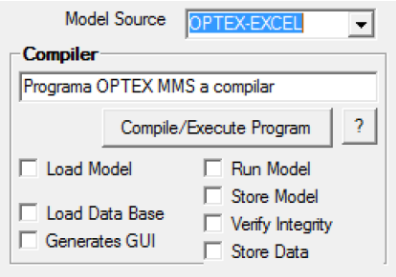
Parallel problems: **Limit the number of parallel problems were handled simultaneously under the parallel optimization option.**

Cores Solver: **Limits the number of cores that can use the solver in the optimization process.**



SOLUTION OF THE MATHEMATICAL MODELS

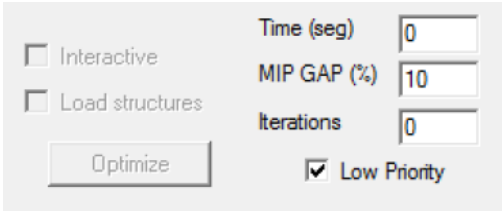
OPTEX-EXE - PROCESSING MODELS EXCEL SECTION



Related process control optimization for models handled in OPTEX-EXCEL-MMS or in OPTEX algebraic language, which is determined by selecting the Source Model.

SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - OPTIMIZATION CONTROL MISCELLANEOUS SECTION



The parameters to define are:

Time Limit: Time limit (in seconds); zero or a negative number indicates NO limit.

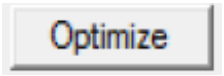
MIP GAP: Percentage for difference (GAP) between primal solution (possible) and dual solution (limit not reached) to be assigned to stop the solution process. Valid numbers between 0 and 100 (%).

Iterations Limit: iteration limit to apply to the solver to solve the problem. Zero or a negative number indicates no limit.

Interactive: Indicates that the optimization process will be make interactively, is only usable for models generated in C.

Load Structures: Indicates that the matrix and vectors of costs and resources are stored to be analyzed with OPTEX-GUI; it is usable only for models that were generated in C.

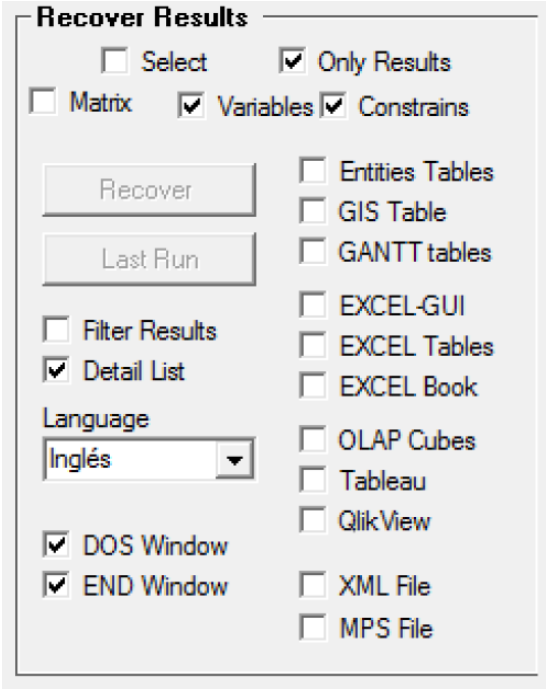
Optimize: Make the optimization process without generating a new program for the model.



SOLUTION OF THE MATHEMATICAL MODELS

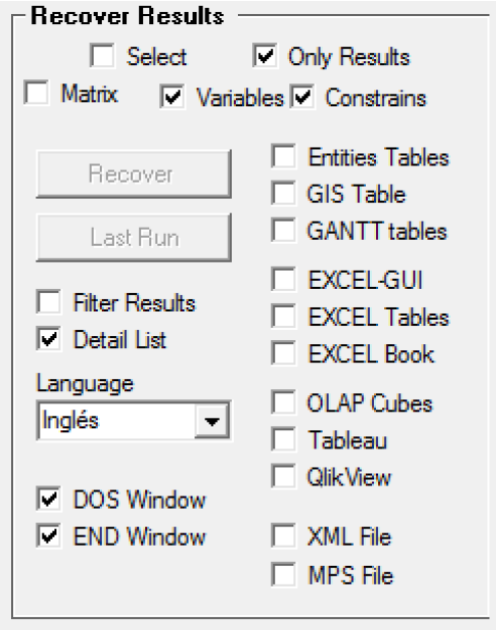
OPTEX-EXE - RECOVERY OF RESULTS SUB-AREA

Related to the control of the recovery of the results process.



SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - CONTROL REPORTS SECTION



Selective: Only the variables and constraints specified for family of scenario are recovered.

Only Results: Activate the option to recover only the value of the primal variables.

Variables: Recovery of variables, generating tables VV_vvv

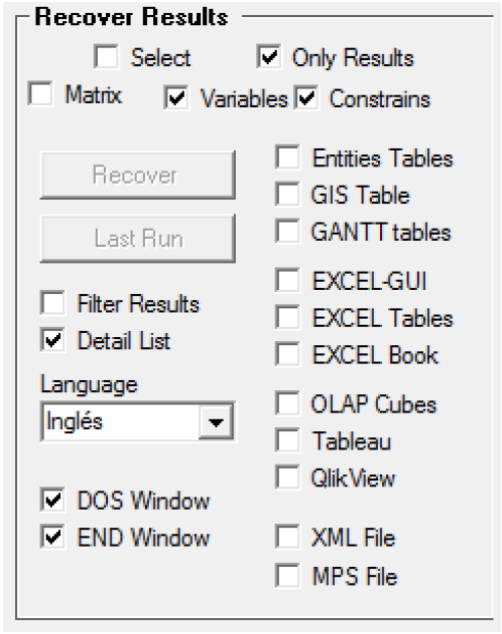
Constraints: Recovery of constrains, generating tables RR_rrr

Filter Results: Indicates that only zero values are recovered.

Detailed List: Indicates that generates a detailed listing of all calculations.

SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - SELECTION REPORTS SECTION



Entities Table: Generates table type EE_eee

GIS Tables: Creating tables connectivity to a GIS system.

GANTT charts: Generates files connectivity to Gantt diagrams in JViews.

EXCEL-GUI: Generate interconnection with OPTEX-EXCEL-GUI.

Tables EXCEL: Produces tables EXCEL-XML

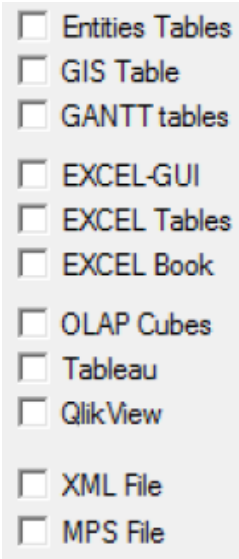
OLAP Cubes: generates connectivity with a server OLAP-MONDRIAN.

TABLEAU: Generates connectivity with TABLEAU (under development)

QLIKVIEW: Generates connectivity with QLIKVIEW (under development)

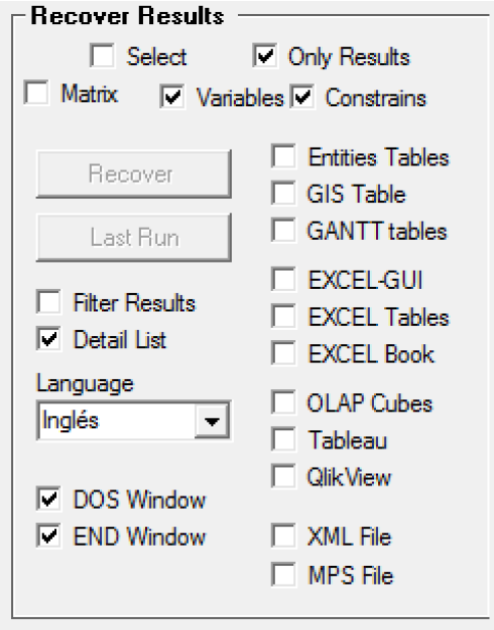
XML Files: Generate files XML

MPS: Generates a file in format MPS



SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - CONTROL WINDOWS SECTION

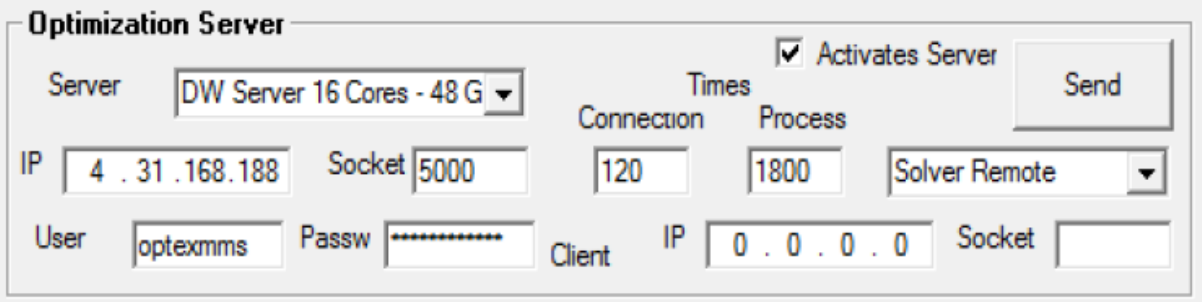


DOS Window: **indicates that running the solver the DOS window with the report will be displayed. Hide this window produces significant reductions in time.**

END Window: **Indicates whether the end of the process with OPTEX is visible or is automatically terminated**

SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - CONTROL WINDOWS SECTION

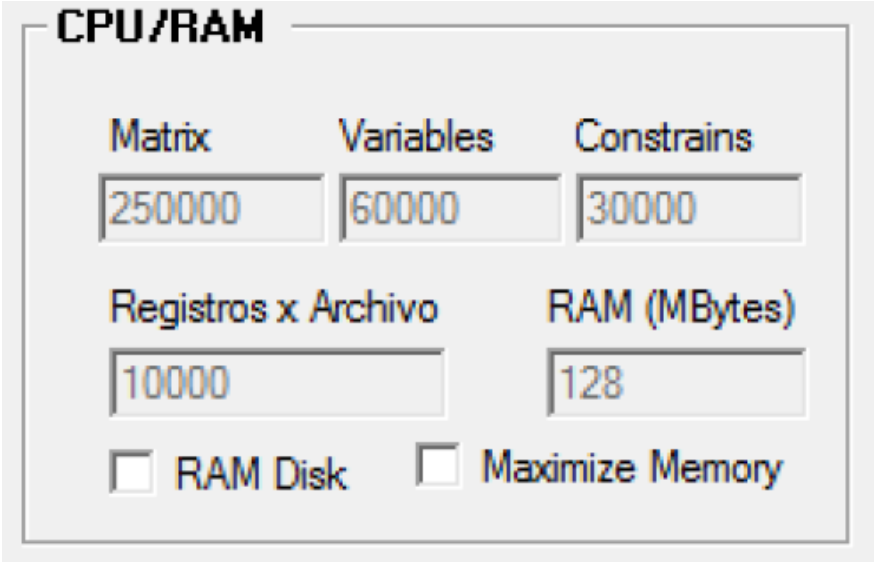


It explained below in section related to such services.

SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE - MEMORY RAM SUB-AREA

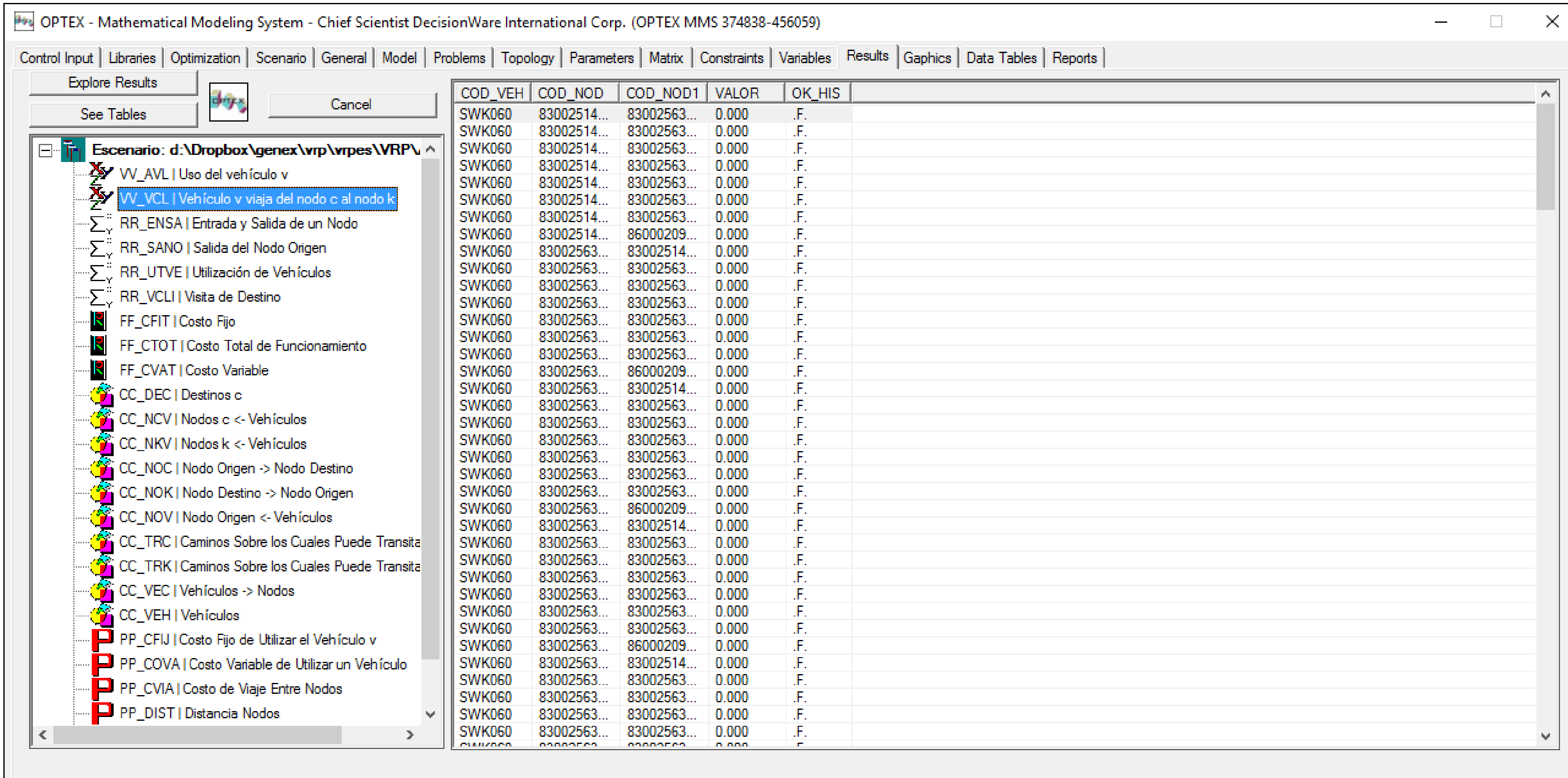
It corresponds to parameters that determine the initial memory allocation to be implemented in the C program generated OPTEX-EXE.



SOLUTION OF THE MATHEMATICAL MODELS

OPTEX-EXE

When the selection process is successful, and if it is instructed in OPTEX-EXE, at the end of the process the user will see the results in an explorer window.



RESULTS INFORMATION SYSTEM

OPTEX generates information that allows the administrator and/or the user to consult, with the level of detail that he wants, the data tables generated in the process of solving a model.

It is available from the coefficients of a variable, or the general structure of an assembled within a matrix, to information that summarizes the activity levels of a variable or its economic assessment in terms of dual variables, and the sets and parameters used by the "solver" to solve mathematical problems.

OPTEX organizes all results of a mathematical model run in an information system that can be explored using the OPTEX-GUI.

TABLES OF RESULTS

The following types of tables of results are generated automatically by OPTEX according to recovery criteria set by the user. The user can get results for:

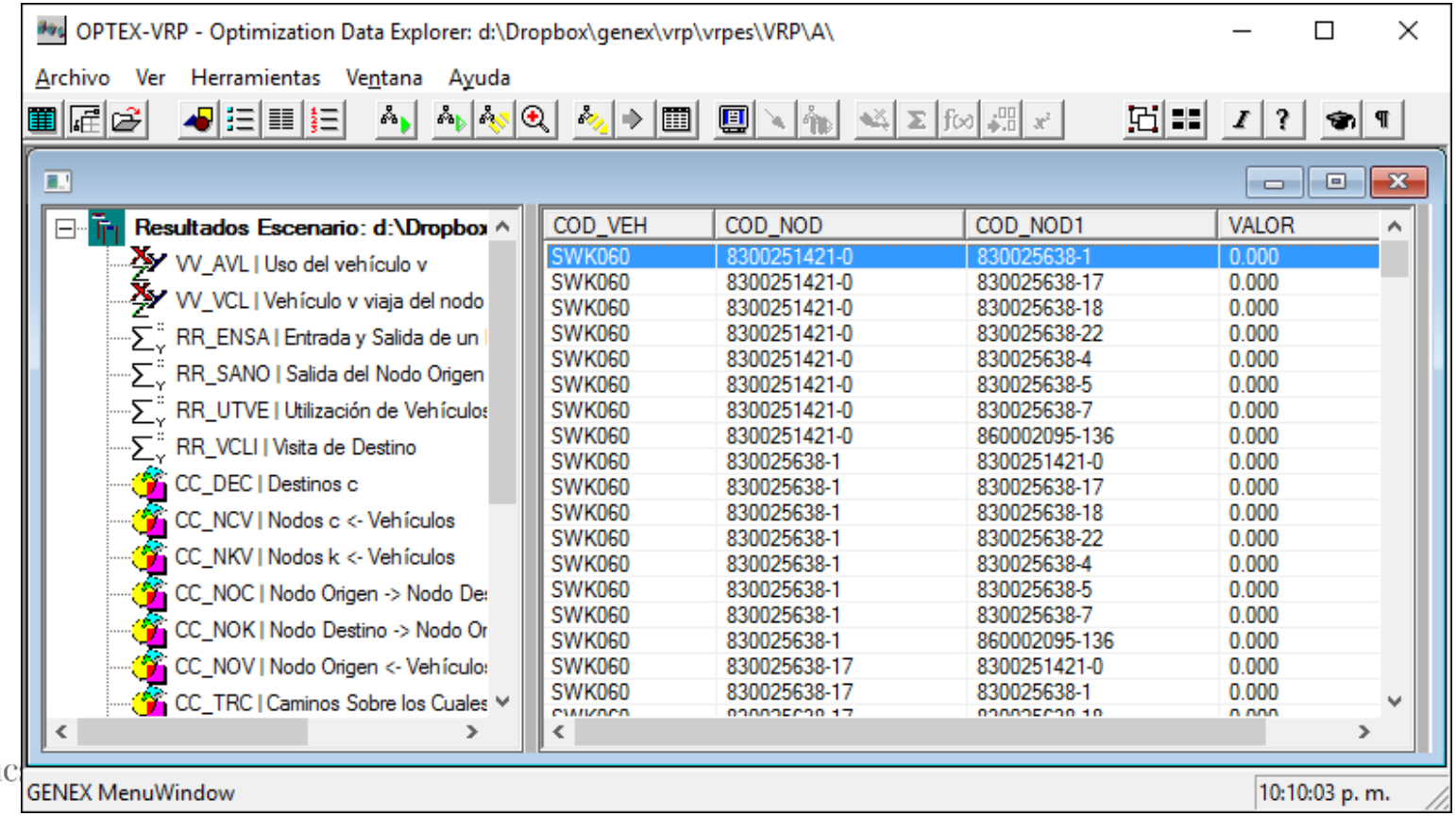
- **Variables**
- **Constraints**
- **Objective Functions**
- **Indexes**
- **Sets**
- **Parameters**

Additional to the relational fields/keys associated with the indexes of variables and constraints (COD_eee and FECHA), the information stored in the tables presented below (the structure should depend on the type of technology):

RESULTS INFORMATION SYSTEM
VARIABLES

VV_vvv tables where vvv is the code variable. Additional to the relational fields this tables include:

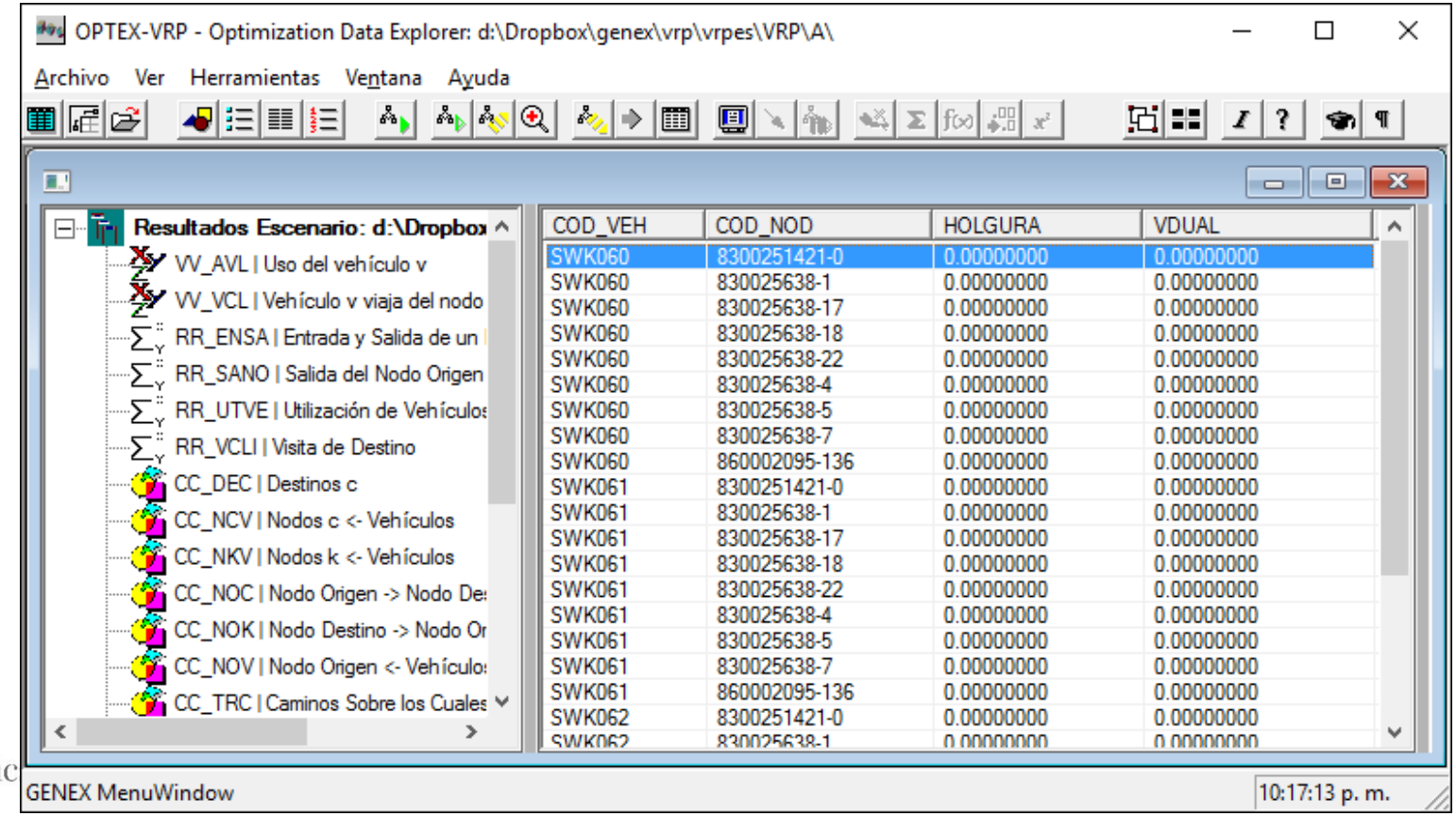
- **VALOR: Value of the variable.**
- **FECHA_HORA: Date-time, for type T variables (continuous time)**
- **COSTO_RED: reduced cost (dual) variable.**
- **COTA_SUP: Upper bound.**
- **COSTO_OBJ: Cost in the objective function**



RESULTS INFORMATION SYSTEM
CONSTRAINTS

RR rrr tables where rrr is the constraint code. Additional to the relational fields this tables include:

- **VDUAL: Value of the dual variable (marginal cost or opportunity cost).**
- **HOLGURA: value of the slack variable.**
- **RECURSO: value of the right side (RHS) of the constraint**



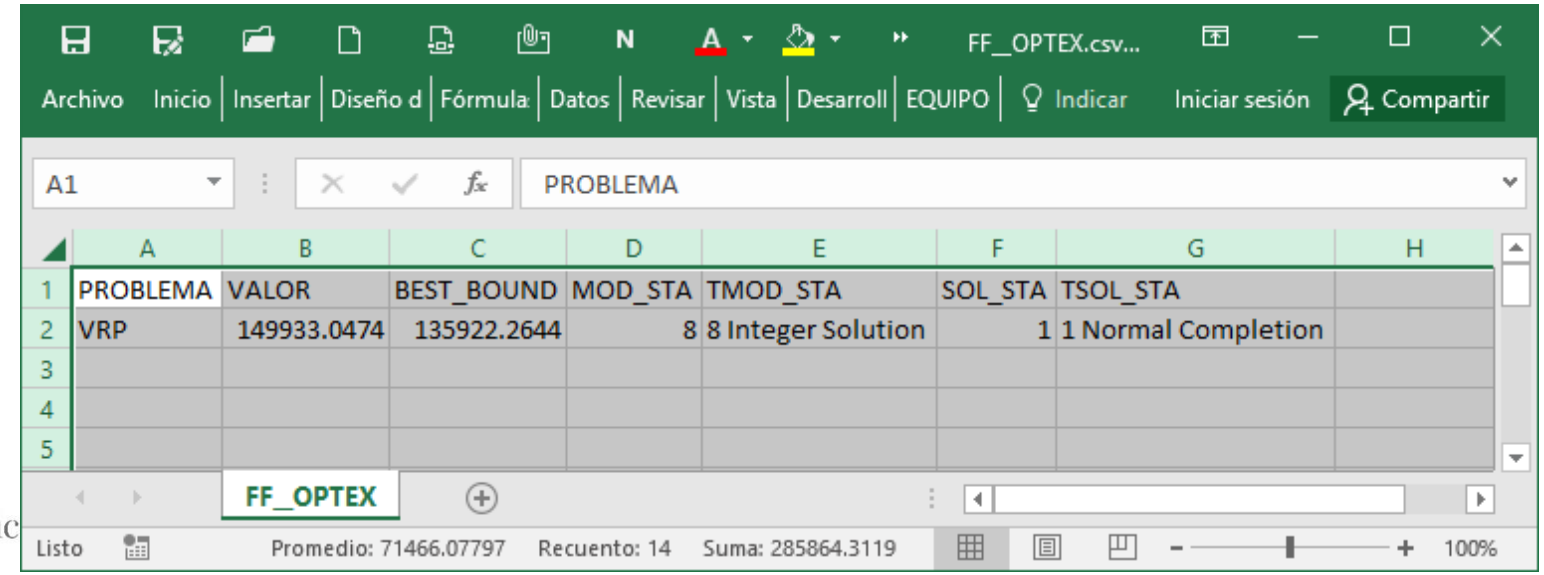
RESULTS INFORMATION SYSTEM
OBJECTIVE FUNTIONS

FF_fff tables where fff is the code of the objective function. Additional to the relational fields this tables include:

- **VALUE: Value of the objective function for all FO.**

For the main FO, additional fields are:

- **PROBLEM: Code Problem**
- **BEST_BOUND: Bound for FO for MIP problems.**
- **MOD_STA: Type Solution (TSO).**
- **TMOD_STA: Description TSO**
- **SOL_STA: Finish Solver Code (FSC).**
- **TSOL_STA: Description FSC.**



	A	B	C	D	E	F	G	H
1	PROBLEMA	VALOR	BEST_BOUND	MOD_STA	TMOD_STA	SOL_STA	TSOL_STA	
2	VRP	149933.0474	135922.2644	8	8 Integer Solution	1	1 Normal Completion	
3								
4								
5								

RESULTS INFORMATION SYSTEM
INDEXES

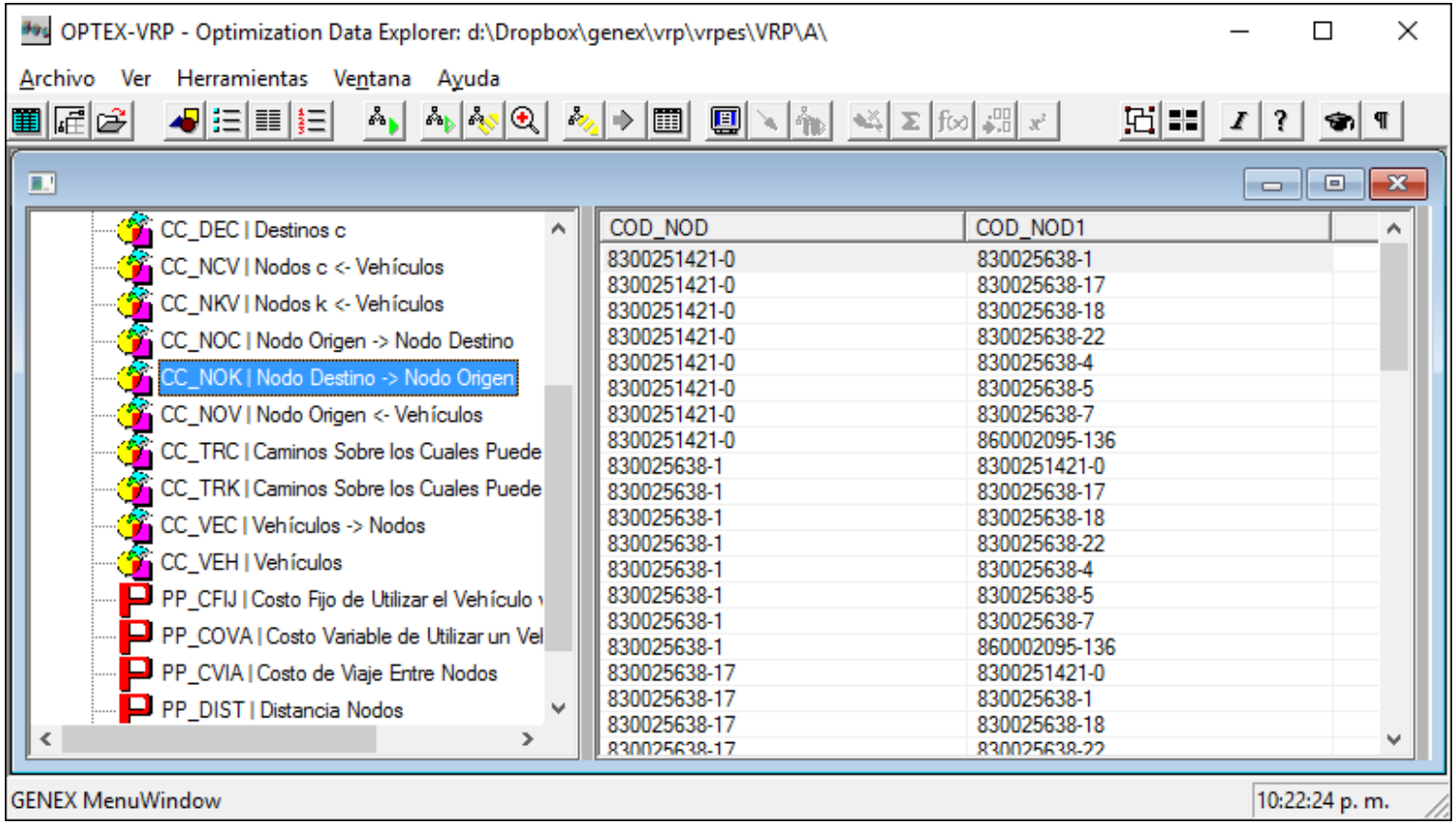
II_ii tables where ii is the index.

Contains the codes of the entities associated with the indices included in model. Contains only one column COD_eee associated with the index.

RESULTS INFORMATION SYSTEM

SETS

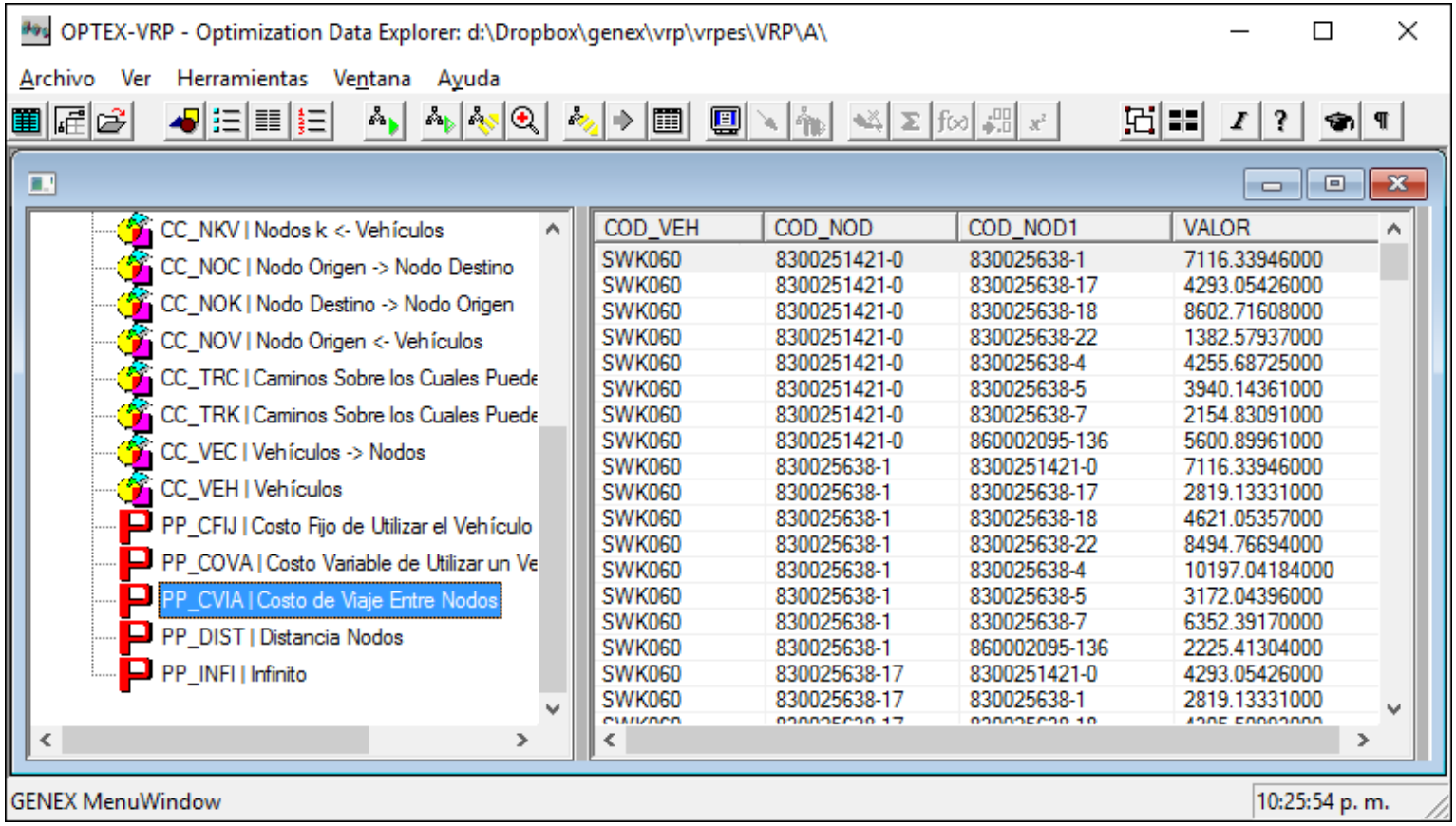
CC_ccc tables where ccc is the code of the set, calculated or read. It contains only fields COD_eee related indexes set.



RESULTS INFORMATION SYSTEM
PARAMETERS

PP_ppp tables where ppp is the parameter code. Additional to the relational fields this tables include:

- **VALOR: Value of the parameter read or calculated.**



RESULTS INFORMATION SYSTEM
RELATIONAL TABLES (EE_eee)

Additionally, OPTEX organizes information according to the relationships between entities (indexes) derived from the set of variables and constraints that have been considered in the model.

This information is stored in tables EE_ii1_ii2_ii3 ... where ii1 corresponds to the index (entity) 1, ii2 index 2, ii3 index 3 and so on to describe all entities that are part of the relationship.

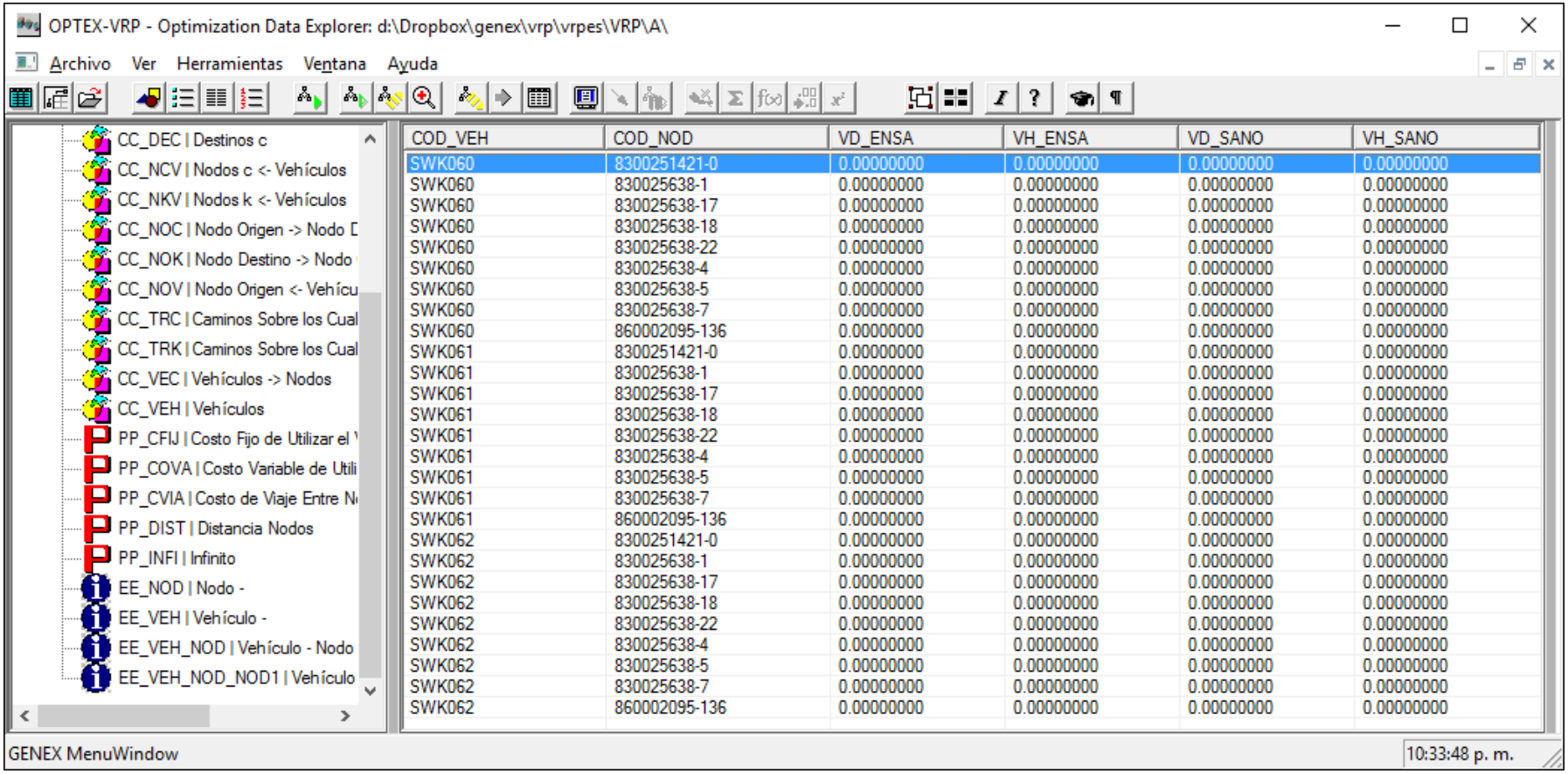
This files including the results for all the variables and constraint associated with the relation (a combination of indexes)

Additional to the relational fields associated with the indexes (COD_eee and FECHA), the information stored in the tables are presented below.

VARIABLES (vvv)	CONSTRAINTS (rrr)
▪ **VA_vvv**: Variable value (primal). ▪ **FH_vvv**: Date-time associated with the value for variable type **T** (continuous-time) ▪ **CR_vvv**: Reduced cost for the variable (dual) ▪ **LO_vvv**: Lower Bound ▪ **UP_vvv**: Upper Bound ▪ **CO_vvv**: Objective Function Cost	▪ **VD_rrr**: Value of the dual. ▪ **VH_rrr**: Value of the slack variable ▪ **RS_rrr**: Value of Right Hand Side (RHS)

If IDIS is supported in DBase tables, these are stored in the directories specified in the application settings; alternatively, if the application drive tables in SQL format, the tables will be stored using an ODBC that controls the access to a TABLESPACE where all tables in the application are defined, in this case to all results tables the fff_eee_ prefix is added, fff which corresponds to the family code and eee to the scenario code.

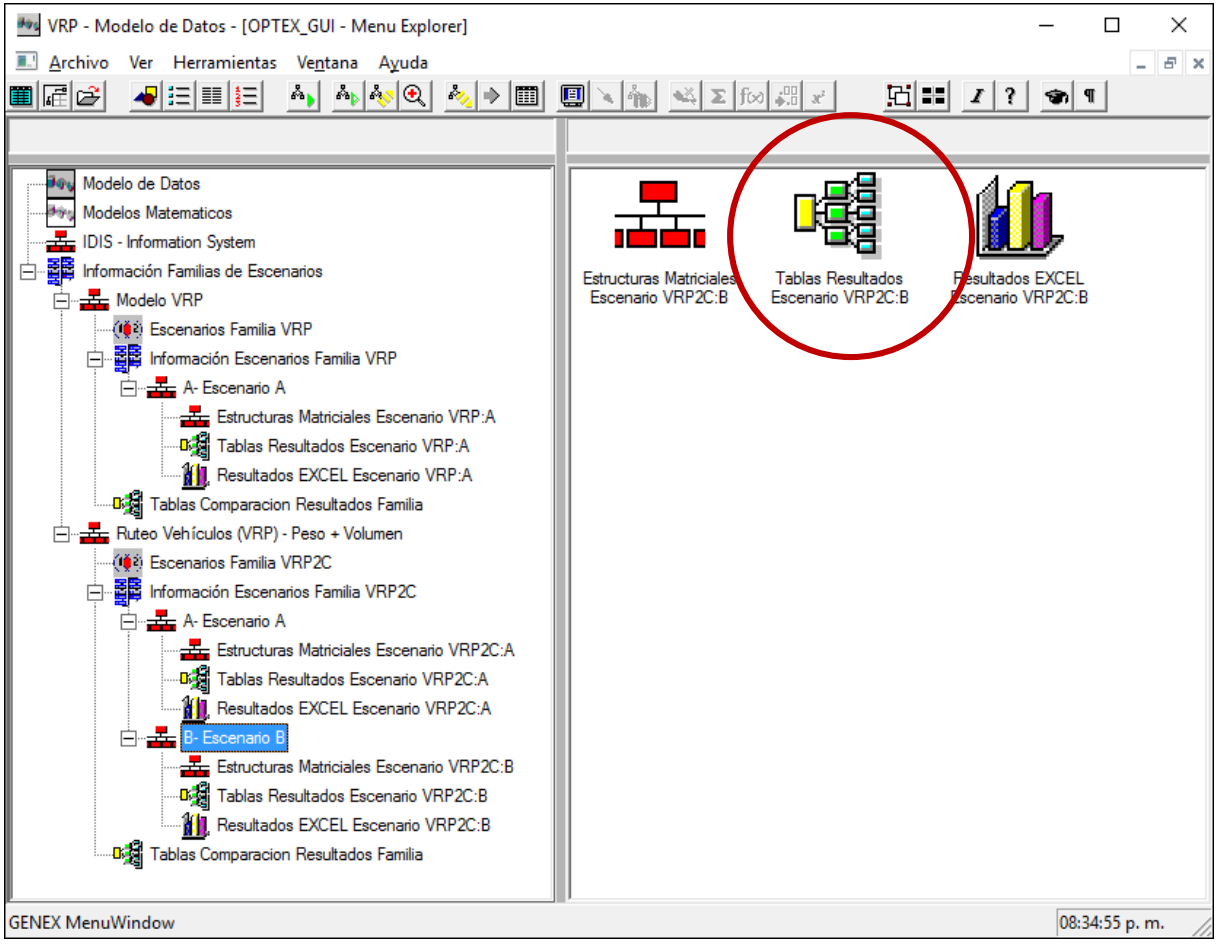
RESULTS INFORMATION SYSTEM
RELATIONAL TABLES (EE_eee)



COD_VEH	COD_NOD	VD_ENSA	VH_ENSA	VD_SANO	VH_SANO
SWK060	8300251421-0	0.00000000	0.00000000	0.00000000	0.00000000
SWK060	830025638-1	0.00000000	0.00000000	0.00000000	0.00000000
SWK060	830025638-17	0.00000000	0.00000000	0.00000000	0.00000000
SWK060	830025638-18	0.00000000	0.00000000	0.00000000	0.00000000
SWK060	830025638-22	0.00000000	0.00000000	0.00000000	0.00000000
SWK060	830025638-4	0.00000000	0.00000000	0.00000000	0.00000000
SWK060	830025638-5	0.00000000	0.00000000	0.00000000	0.00000000
SWK060	830025638-7	0.00000000	0.00000000	0.00000000	0.00000000
SWK060	860002095-136	0.00000000	0.00000000	0.00000000	0.00000000
SWK061	8300251421-0	0.00000000	0.00000000	0.00000000	0.00000000
SWK061	830025638-1	0.00000000	0.00000000	0.00000000	0.00000000
SWK061	830025638-17	0.00000000	0.00000000	0.00000000	0.00000000
SWK061	830025638-18	0.00000000	0.00000000	0.00000000	0.00000000
SWK061	830025638-22	0.00000000	0.00000000	0.00000000	0.00000000
SWK061	830025638-4	0.00000000	0.00000000	0.00000000	0.00000000
SWK061	830025638-5	0.00000000	0.00000000	0.00000000	0.00000000
SWK061	830025638-7	0.00000000	0.00000000	0.00000000	0.00000000
SWK061	860002095-136	0.00000000	0.00000000	0.00000000	0.00000000
SWK062	8300251421-0	0.00000000	0.00000000	0.00000000	0.00000000
SWK062	830025638-1	0.00000000	0.00000000	0.00000000	0.00000000
SWK062	830025638-17	0.00000000	0.00000000	0.00000000	0.00000000
SWK062	830025638-18	0.00000000	0.00000000	0.00000000	0.00000000
SWK062	830025638-22	0.00000000	0.00000000	0.00000000	0.00000000
SWK062	830025638-4	0.00000000	0.00000000	0.00000000	0.00000000
SWK062	830025638-5	0.00000000	0.00000000	0.00000000	0.00000000
SWK062	830025638-7	0.00000000	0.00000000	0.00000000	0.00000000
SWK062	860002095-136	0.00000000	0.00000000	0.00000000	0.00000000

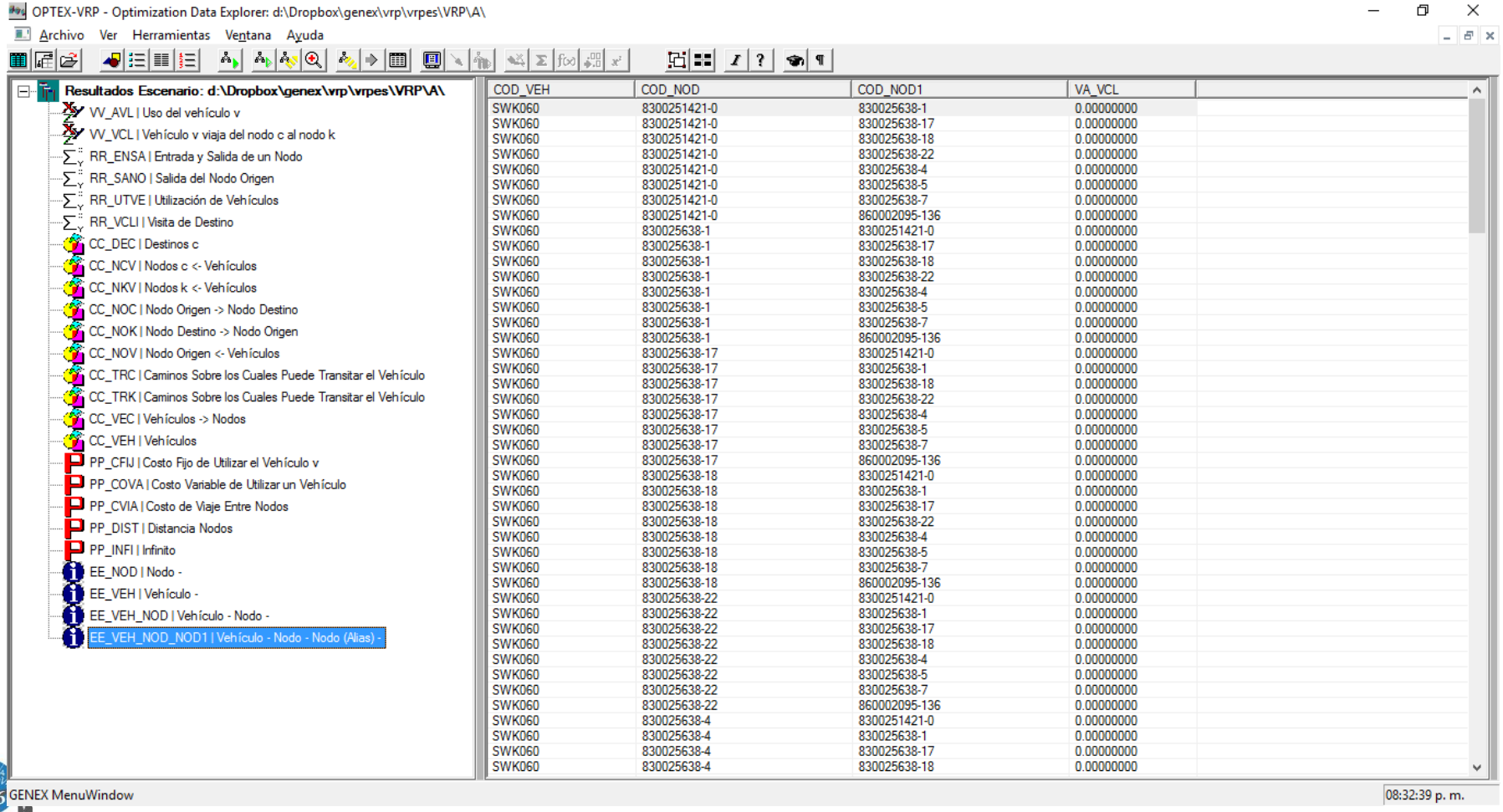
RESULTS INFORMATION SYSTEM
DISPLAY RESULTS VIA OPTEX-GUI

The optimization results are available for any scenario through OPTEX-GUI browser, following the menu the user can access to Scenario Family's Information System, whose consultation is guided by OPTEX-GUI.



RESULTS INFORMATION SYSTEM
DISPLAY RESULTS VIA OPTEX-GUI

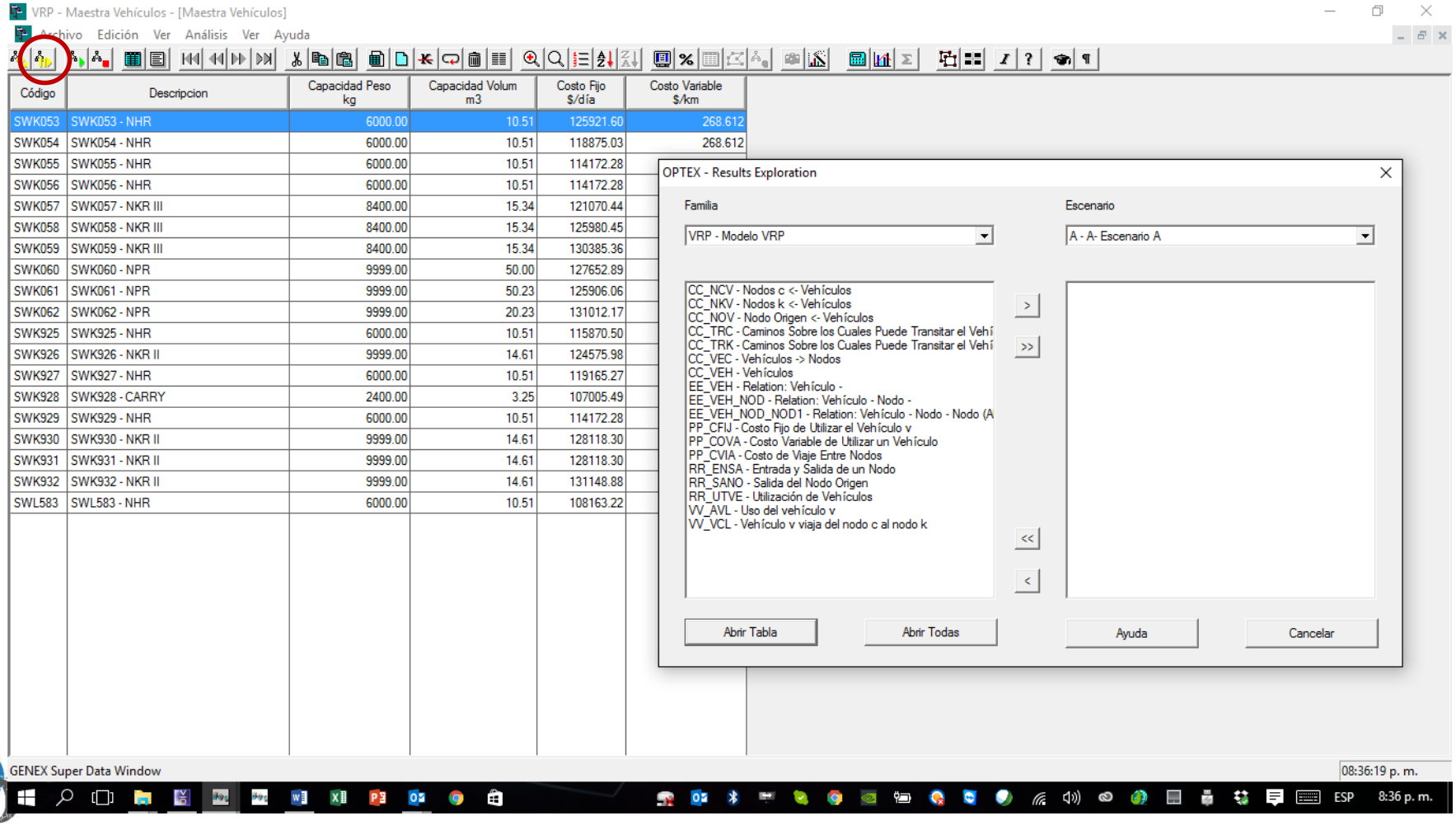
The user can view all the results tables of a scenario accessing the Result Scenario Tables option, as shown in the following figure.



COD_VEH	COD_NOD	COD_NOD1	VA_VCL
SWK060	8300251421-0	830025638-1	0.00000000
SWK060	8300251421-0	830025638-17	0.00000000
SWK060	8300251421-0	830025638-18	0.00000000
SWK060	8300251421-0	830025638-22	0.00000000
SWK060	8300251421-0	830025638-4	0.00000000
SWK060	8300251421-0	830025638-5	0.00000000
SWK060	8300251421-0	830025638-7	0.00000000
SWK060	8300251421-0	860002095-136	0.00000000
SWK060	830025638-1	8300251421-0	0.00000000
SWK060	830025638-1	830025638-17	0.00000000
SWK060	830025638-1	830025638-18	0.00000000
SWK060	830025638-1	830025638-22	0.00000000
SWK060	830025638-1	830025638-4	0.00000000
SWK060	830025638-1	830025638-5	0.00000000
SWK060	830025638-1	830025638-7	0.00000000
SWK060	830025638-1	860002095-136	0.00000000
SWK060	830025638-17	8300251421-0	0.00000000
SWK060	830025638-17	830025638-1	0.00000000
SWK060	830025638-17	830025638-18	0.00000000
SWK060	830025638-17	830025638-22	0.00000000
SWK060	830025638-17	830025638-4	0.00000000
SWK060	830025638-17	830025638-5	0.00000000
SWK060	830025638-17	830025638-7	0.00000000
SWK060	830025638-17	860002095-136	0.00000000
SWK060	830025638-18	8300251421-0	0.00000000
SWK060	830025638-18	830025638-1	0.00000000
SWK060	830025638-18	830025638-17	0.00000000
SWK060	830025638-18	830025638-22	0.00000000
SWK060	830025638-18	830025638-4	0.00000000
SWK060	830025638-18	830025638-5	0.00000000
SWK060	830025638-18	830025638-7	0.00000000
SWK060	830025638-18	860002095-136	0.00000000
SWK060	830025638-22	8300251421-0	0.00000000
SWK060	830025638-22	830025638-1	0.00000000
SWK060	830025638-22	830025638-17	0.00000000
SWK060	830025638-22	830025638-18	0.00000000
SWK060	830025638-22	830025638-4	0.00000000
SWK060	830025638-22	830025638-5	0.00000000
SWK060	830025638-22	830025638-7	0.00000000
SWK060	830025638-22	860002095-136	0.00000000
SWK060	830025638-4	8300251421-0	0.00000000
SWK060	830025638-4	830025638-1	0.00000000
SWK060	830025638-4	830025638-17	0.00000000
SWK060	830025638-4	830025638-18	0.00000000

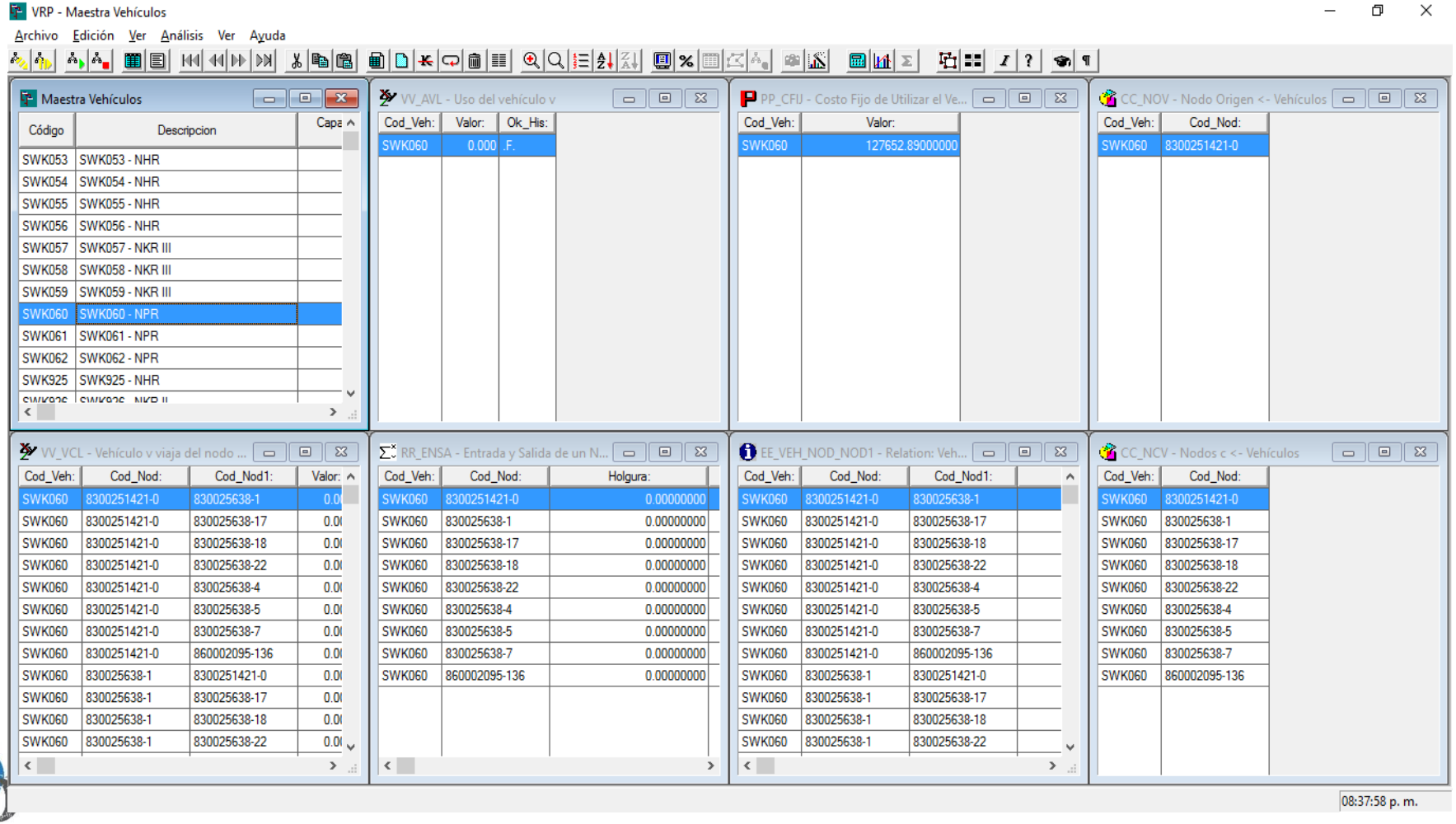
RESULTS INFORMATION SYSTEM
DISPLAY RESULTS VIA OPTEX-GUI

Alternatively, the user can view the results from the master tables and tables of scenarios; to do this, the user selects the Open Table(s) Result(s) option from the menu of data window that displays all result tables related to the entity, for it must select the family and the scenario that the user want to explore.



RESULTS INFORMATION SYSTEM
DISPLAY RESULTS VIA OPTEX-GUI

The following figure presents an example of the query results for specific physical entity.



RESULTS INFORMATION SYSTEM
DISPLAY RESULTS VIA OPTEX-EXCEL-GUI

All results of mathematical models can be viewed and analyzed in OPTEX-EXCEL-GUI that corresponding to a graphical interface based on EXCEL using dynamics tables and dynamics graphs. The interested reader is invited to consult the Manual OPTEX-EXCEL-GUI User.

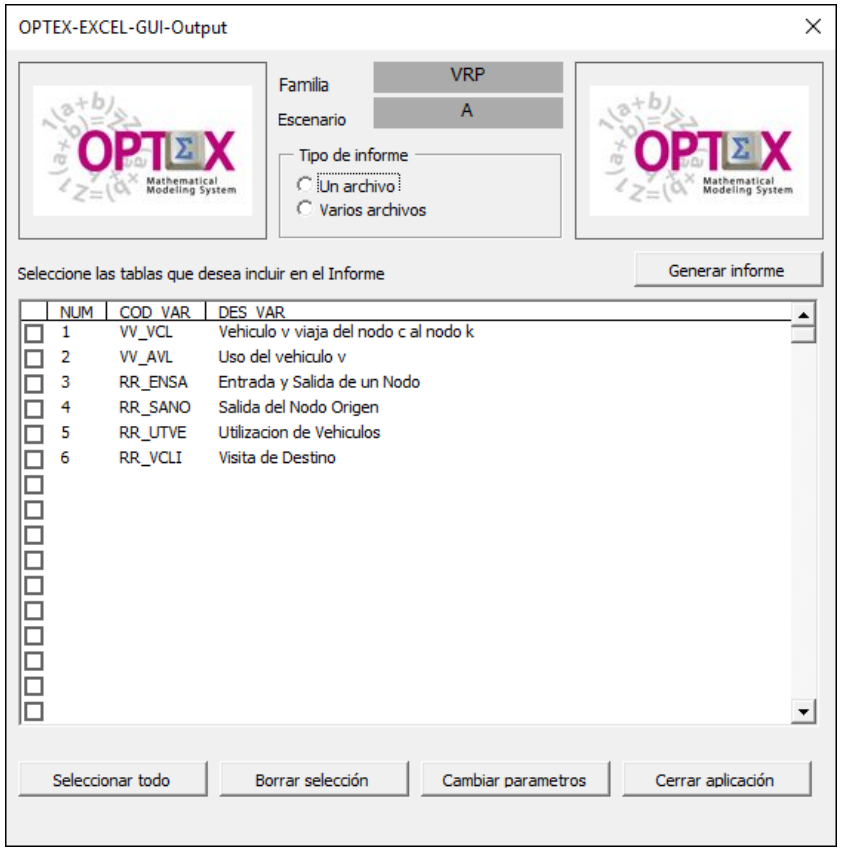
OPTEX-EXCEL-GUI is handled by a control window that is accessed by the user to define the report required.

For each variable, or constraint, three sheets are generated with the following information:

- **DATA: Raw Data (CSV)**
- **TD: Pivot Table**
- **GRF: Pivot Graph (Dynamic Graphics)**

The sheet will be named by concatenating the following codes:

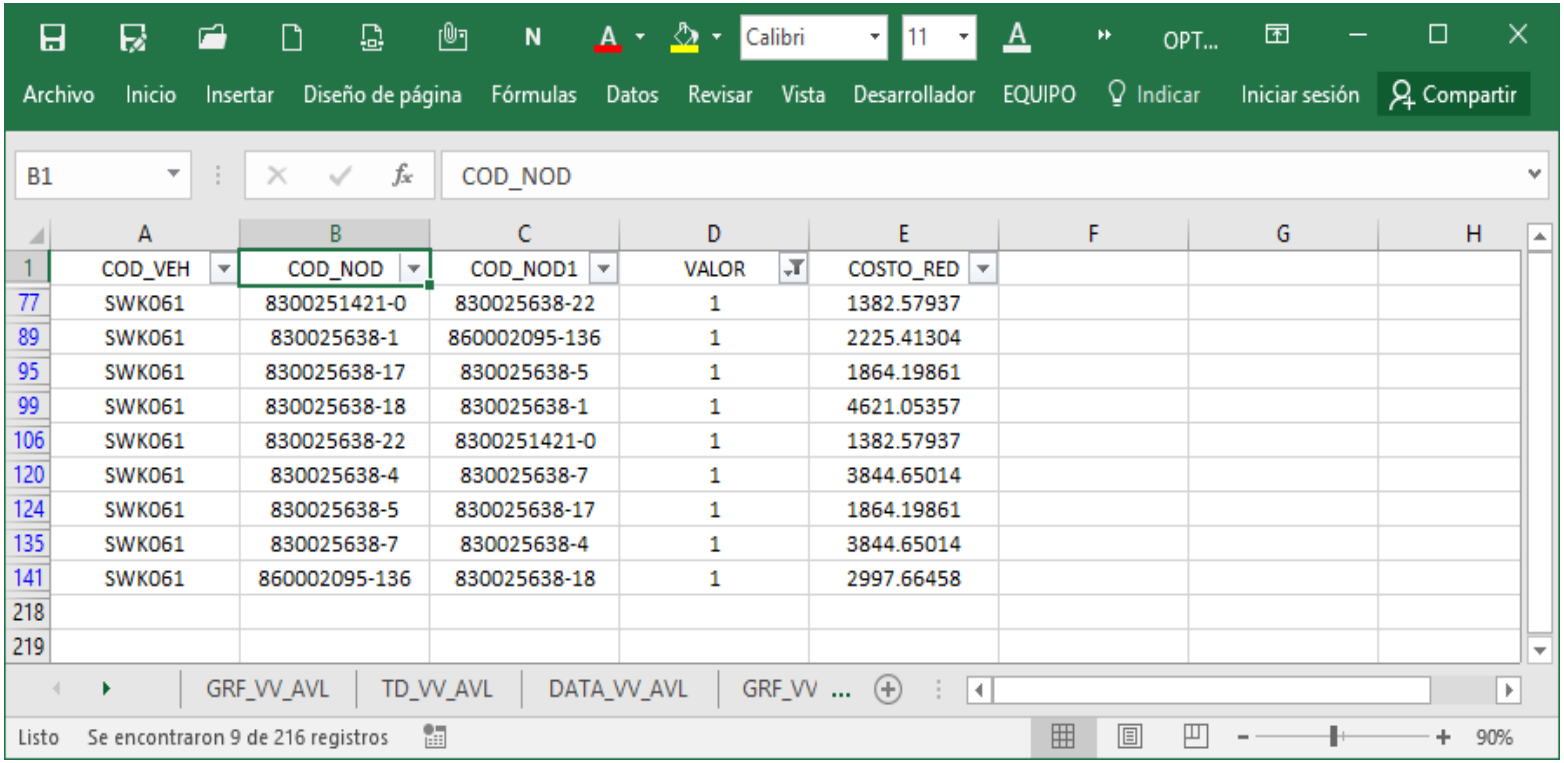
- **Type of sheet (DATA, TD or GRF);**
- **Type of item (VV or RR) and iii) the variable code or the constraints code.**



RESULTS INFORMATION SYSTEM

DISPLAY RESULTS VIA OPTEX-EXCEL-GUI

CSV (RAW) TABLE

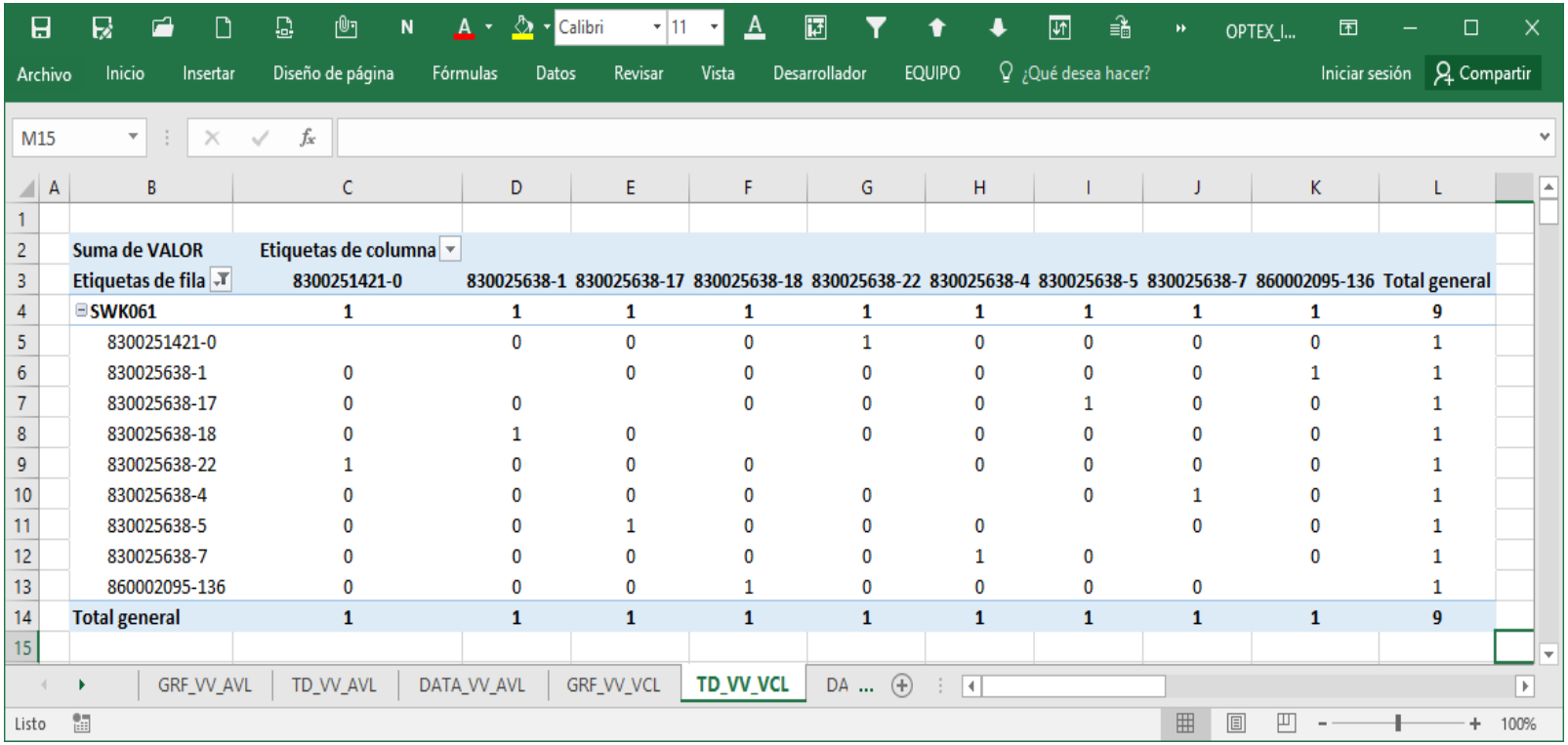


	A	B	C	D	E	F	G	H
1	COD_VEH	COD_NOD	COD_NOD1	VALOR	COSTO_RED			
77	SWK061	8300251421-0	830025638-22	1	1382.57937			
89	SWK061	830025638-1	860002095-136	1	2225.41304			
95	SWK061	830025638-17	830025638-5	1	1864.19861			
99	SWK061	830025638-18	830025638-1	1	4621.05357			
106	SWK061	830025638-22	8300251421-0	1	1382.57937			
120	SWK061	830025638-4	830025638-7	1	3844.65014			
124	SWK061	830025638-5	830025638-17	1	1864.19861			
135	SWK061	830025638-7	830025638-4	1	3844.65014			
141	SWK061	860002095-136	830025638-18	1	2997.66458			
218								
219								

RESULTS INFORMATION SYSTEM

DISPLAY RESULTS VIA OPTEX-EXCEL-GUI

PIVOT TABLE



Archivo Inicio Insertar Diseño de página Fórmulas Datos Revisar Vista Desarrollador EQUIPO ¿Qué desea hacer? Iniciar sesión Compartir

M15

Suma de VALOR	Etiquetas de columna									
Etiquetas de fila	8300251421-0	830025638-1	830025638-17	830025638-18	830025638-22	830025638-4	830025638-5	830025638-7	860002095-136	Total general
SWK061	1	1	1	1	1	1	1	1	1	9
8300251421-0		0	0	0	1	0	0	0	0	1
830025638-1	0		0	0	0	0	0	0	1	1
830025638-17	0	0		0	0	0	1	0	0	1
830025638-18	0	1	0		0	0	0	0	0	1
830025638-22	1	0	0	0		0	0	0	0	1
830025638-4	0	0	0	0	0		0	1	0	1
830025638-5	0	0	1	0	0	0		0	0	1
830025638-7	0	0	0	0	0	1	0		0	1
860002095-136	0	0	0	1	0	0	0	0		1
Total general	1	1	1	1	1	1	1	1	1	9

GRF_VV_AVL TD_VV_AVL DATA_VV_AVL GRF_VV_VCL TD_VV_VCL DA ...

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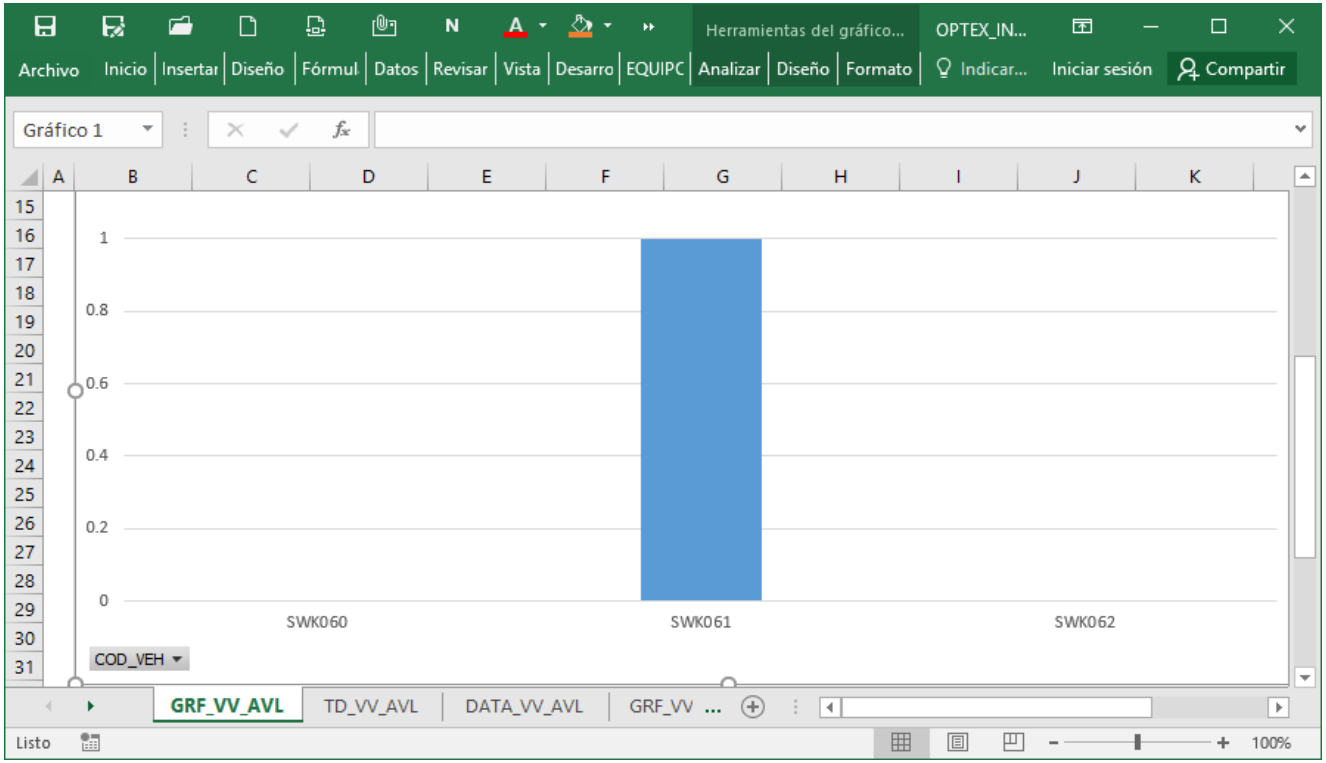
Analytics

RESULTS INFORMATION SYSTEM

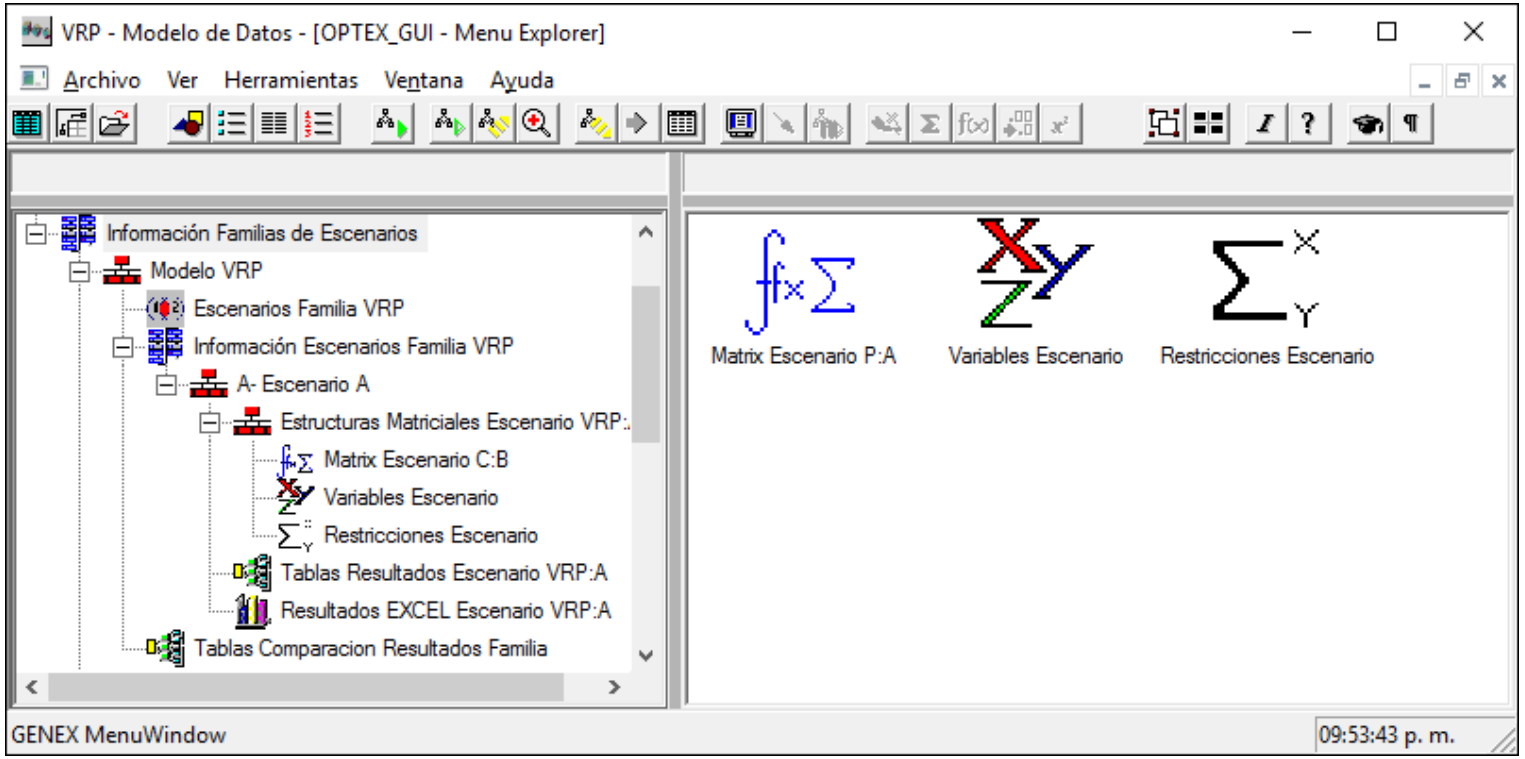
DISPLAY RESULTS VIA OPTEX-EXCEL-GUI

PIVOT (DYNAMIC) GRAPH



RESULTS INFORMATION SYSTEM
TABLES WITH MATRIX STRUCTURES

When available (depend of optimization technology), OPTEX matrix structures stored in tables of the information system to allow consultation through OPTEX-GUI. When available, and the user requests, OPTEX stores matrix structures related to the model in three tables located in the directory of the scenario.



RESULTS INFORMATION SYSTEM
TABLES WITH MATRIX STRUCTURES

MAT_ESC: Expanded Matrix. It allows the user to review the matrix used in the mathematical model. Apply for problems with linear constraints.

VRP - Expanded Matrix - [Expanded Matrix]

Archivo Edición Ver Análisis Ver Ayuda

ID Expand.Constraint	ID Expanded Variable	Coefficient	Problem	ID Restriccion	ID Variable	Serial Constraint	Serial Variable
ENSA_SWK060_8300251421-0	VCL_SWK060_8300251421-0_830025638-1	1.				1	1
ENSA_SWK060_8300251421-0	VCL_SWK060_830025638-17_8300251421-0	-1.				1	10
ENSA_SWK060_8300251421-0	VCL_SWK060_830025638-18_8300251421-0	-1.				1	11
ENSA_SWK060_8300251421-0	VCL_SWK060_830025638-22_8300251421-0	-1.				1	12
ENSA_SWK060_8300251421-0	VCL_SWK060_830025638-4_8300251421-0	-1.				1	13
ENSA_SWK060_8300251421-0	VCL_SWK060_830025638-5_8300251421-0	-1.				1	14
ENSA_SWK060_8300251421-0	VCL_SWK060_830025638-7_8300251421-0	-1.				1	15
ENSA_SWK060_8300251421-0	VCL_SWK060_860002095-136_8300251421-0	-1.				1	16
ENSA_SWK060_8300251421-0	VCL_SWK060_8300251421-0_830025638-17	1.				1	2
ENSA_SWK060_8300251421-0	VCL_SWK060_8300251421-0_830025638-18	1.				1	3
ENSA_SWK060_8300251421-0	VCL_SWK060_8300251421-0_830025638-22	1.				1	4
ENSA_SWK060_8300251421-0	VCL_SWK060_8300251421-0_830025638-4	1.				1	5
ENSA_SWK060_8300251421-0	VCL_SWK060_8300251421-0_830025638-5	1.				1	6
ENSA_SWK060_8300251421-0	VCL_SWK060_8300251421-0_830025638-7	1.				1	7
ENSA_SWK060_8300251421-0	VCL_SWK060_8300251421-0_860002095-136	1.				1	8
ENSA_SWK060_8300251421-0	VCL_SWK060_830025638-1_8300251421-0	-1.				1	9
ENSA_SWK061_8300251421-0	VCL_SWK061_8300251421-0_830025638-1	1.				10	73
ENSA_SWK061_8300251421-0	VCL_SWK061_8300251421-0_830025638-17	1.				10	74
ENSA_SWK061_8300251421-0	VCL_SWK061_8300251421-0_830025638-18	1.				10	75
ENSA_SWK061_8300251421-0	VCL_SWK061_8300251421-0_830025638-22	1.				10	76
ENSA_SWK061_8300251421-0	VCL_SWK061_8300251421-0_830025638-4	1.				10	77
ENSA_SWK061_8300251421-0	VCL_SWK061_8300251421-0_830025638-5	1.				10	78
ENSA_SWK061_8300251421-0	VCL_SWK061_8300251421-0_830025638-7	1.				10	79
ENSA_SWK061_8300251421-0	VCL_SWK061_8300251421-0_860002095-136	1.				10	80
ENSA_SWK061_8300251421-0	VCL_SWK061_830025638-1_8300251421-0	-1.				10	81
ENSA_SWK061_8300251421-0	VCL_SWK061_830025638-17_8300251421-0	-1.				10	82
ENSA_SWK061_8300251421-0	VCL_SWK061_830025638-18_8300251421-0	-1.				10	83
ENSA_SWK061_8300251421-0	VCL_SWK061_830025638-22_8300251421-0	-1.				10	84
ENSA_SWK061_8300251421-0	VCL_SWK061_830025638-4_8300251421-0	-1.				10	85
ENSA_SWK061_8300251421-0	VCL_SWK061_830025638-5_8300251421-0	-1.				10	86
ENSA_SWK061_8300251421-0	VCL_SWK061_830025638-7_8300251421-0	-1.				10	87

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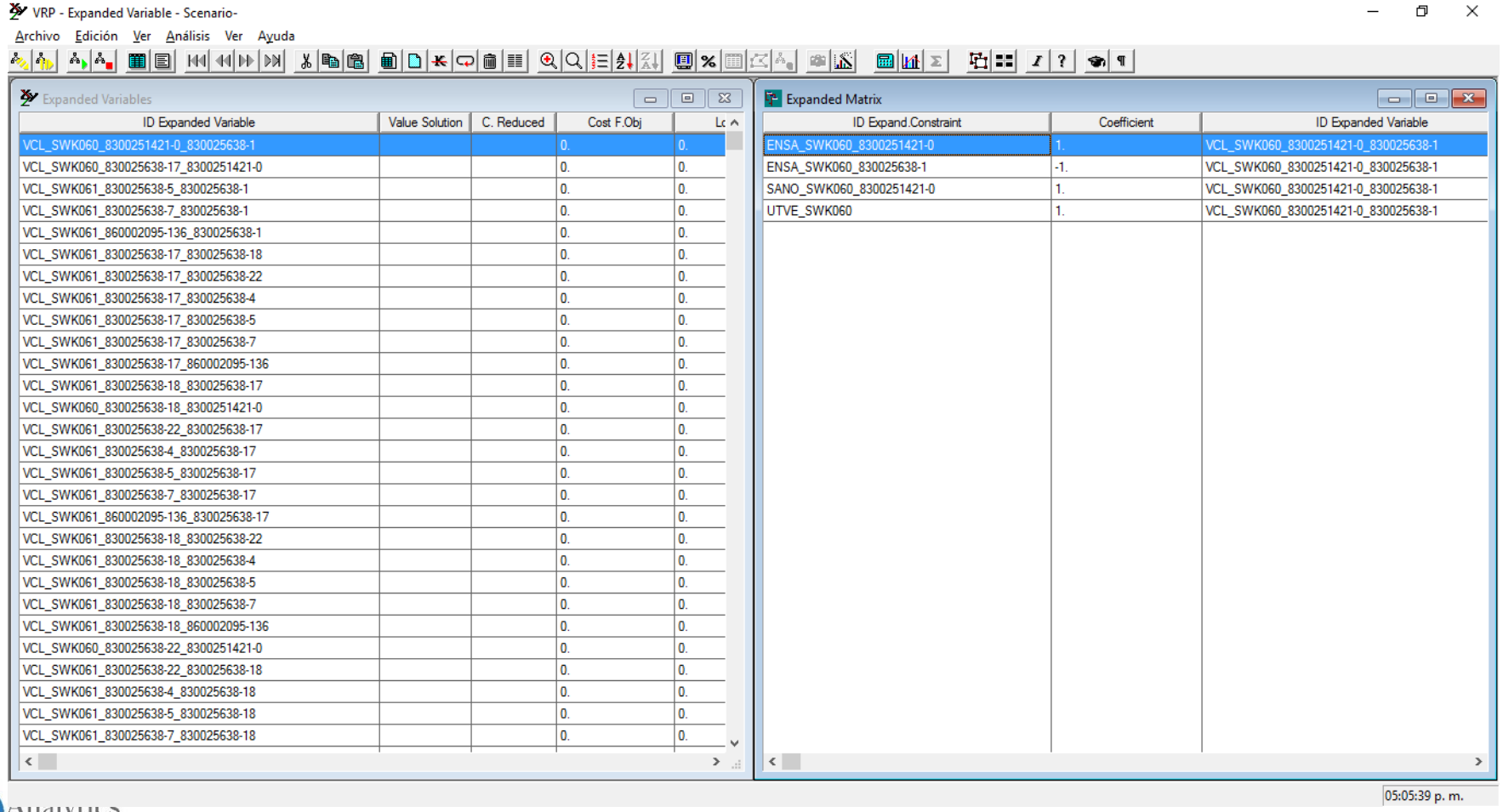
RESULTS INFORMATION SYSTEM
TABLES WITH MATRIX STRUCTURES

VAR_ESC: Expanded Variables. It allows the user to review the matrix structures from the point of view of the variables indicating in which constraints is included a specific variable. This requires access MAT_ESC tables from the Open Table (s) Related (s) option.

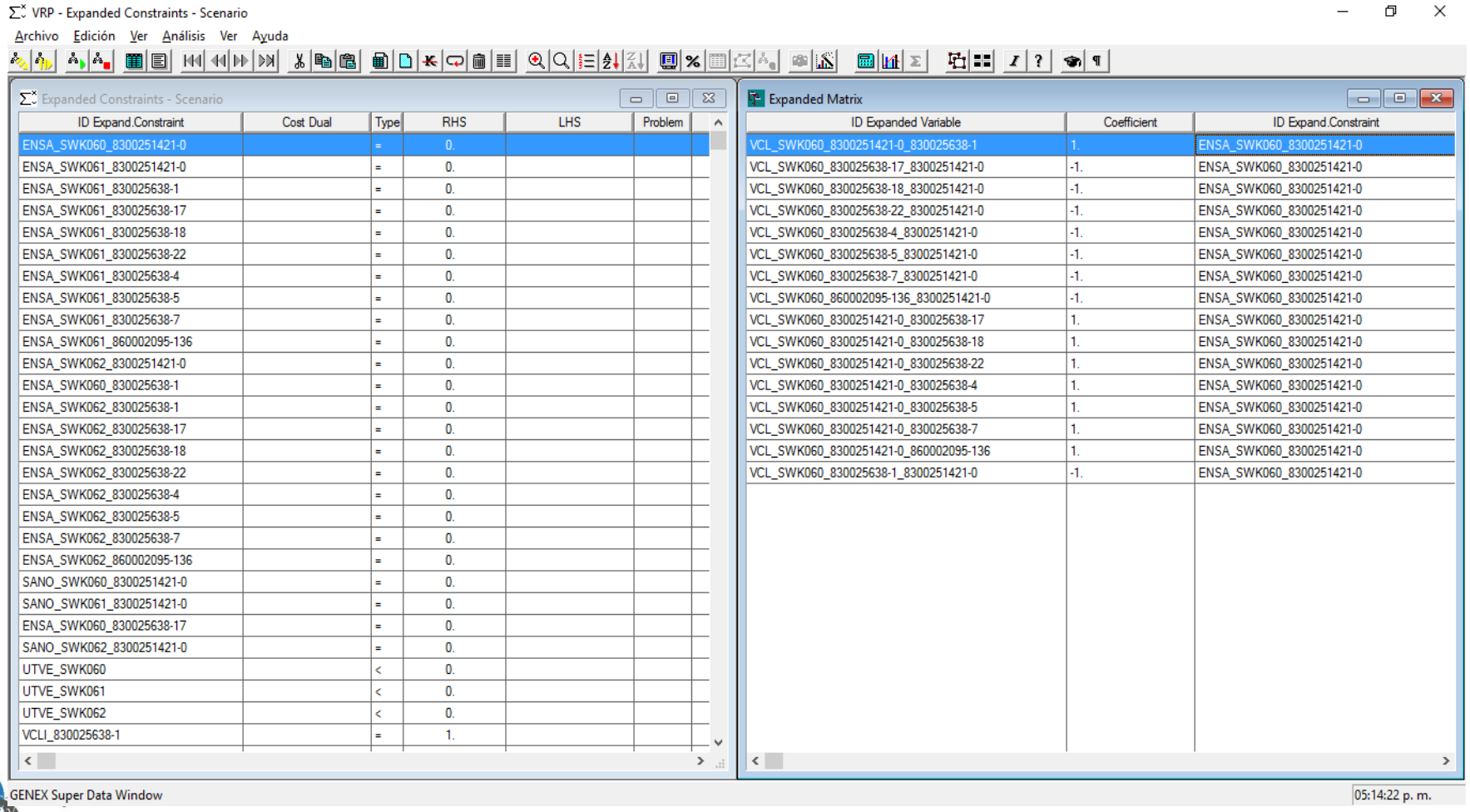


ID Expanded Variable	Value Solution	C. Reduced	Cost F.Obj	Lc
VCL_SWK060_8300251421-0_830025638-1			0.	0.
VCL_SWK060_830025638-17_8300251421-0			0.	0.
VCL_SWK061_830025638-5_830025638-1			0.	0.
VCL_SWK061_830025638-7_830025638-1			0.	0.
VCL_SWK061_860002095-136_830025638-1			0.	0.
VCL_SWK061_830025638-17_830025638-18			0.	0.
VCL_SWK061_830025638-17_830025638-22			0.	0.
VCL_SWK061_830025638-17_830025638-4			0.	0.
VCL_SWK061_830025638-17_830025638-5			0.	0.
VCL_SWK061_830025638-17_830025638-7			0.	0.
VCL_SWK061_830025638-17_860002095-136			0.	0.
VCL_SWK061_830025638-18_830025638-17			0.	0.
VCL_SWK060_830025638-18_8300251421-0			0.	0.
VCL_SWK061_830025638-22_830025638-17			0.	0.
VCL_SWK061_830025638-4_830025638-17			0.	0.
VCL_SWK061_830025638-5_830025638-17			0.	0.
VCL_SWK061_830025638-7_830025638-17			0.	0.
VCL_SWK061_860002095-136_830025638-17			0.	0.
VCL_SWK061_830025638-18_830025638-22			0.	0.
VCL_SWK061_830025638-18_830025638-4			0.	0.
VCL_SWK061_830025638-18_830025638-5			0.	0.
VCL_SWK061_830025638-18_830025638-7			0.	0.
VCL_SWK061_830025638-18_860002095-136			0.	0.
VCL_SWK060_830025638-22_8300251421-0			0.	0.
VCL_SWK061_830025638-22_830025638-18			0.	0.
VCL_SWK061_830025638-4_830025638-18			0.	0.
VCL_SWK061_830025638-5_830025638-18			0.	0.
VCL_SWK061_830025638-7_830025638-18			0.	0.

ID Expand.Constraint	Coefficient	ID Expanded Variable
ENSA_SWK060_8300251421-0	1.	VCL_SWK060_8300251421-0_830025638-1
ENSA_SWK060_830025638-1	-1.	VCL_SWK060_8300251421-0_830025638-1
SANO_SWK060_8300251421-0	1.	VCL_SWK060_8300251421-0_830025638-1
UTVE_SWK060	1.	VCL_SWK060_8300251421-0_830025638-1

RESULTS INFORMATION SYSTEM
TABLES WITH MATRIX STRUCTURES

RES_ESC: Expanded Contraints. It allows the user to review the matrix structures from the point of view of the constraints, indicating which variables are included in a specific constraint. This requires access MAT_ESC tables from the Open Table (s) Related (s) option.



Analytics

"the computer-based mathematical modeling is the greatest invention of all times"

Herbert Simon
First Winner of Nobel Prize in Economics (1978)

"for his pioneering research into the decision-making process within economic organizations"