RCADT
Research Center for
Advanced Decision Technologies

THE NEW APPROACH TO MAKE HIGH COMPLEXITY LARGE-SCALE MATHEMATICAL MODELS

by
RCADT Inc.
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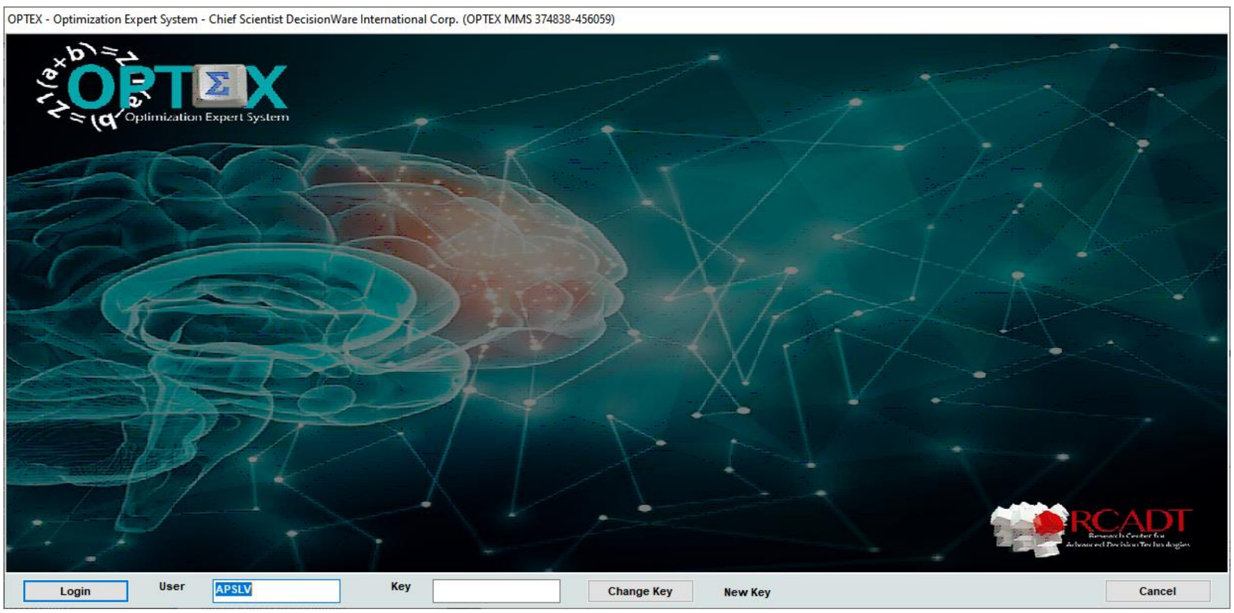
OPTEX Optimization Expert System

The New Approach to Make High Complexity Large-scale Mathematical Models

1. INTRODUCTION

OPTEX Optimization Expert System (hereinafter OPTEX) is the **Research Center for Advanced Decision Technologies Inc. (RCADT)** optimization technology oriented to produce Artificial Hypothalamus as the technological and logic, evolution of the current Decision Support Systems (DSS) moved by humans. This new form of management can be called **Organization 4.0** and it is based on the concepts of "Enterprise-Wide Optimization".

OPTEX is the result of more than thirty (30) years of experience in multiple optimization projects applied to real life problems, developed in several countries, economic sectors, and cultures.



OPTEX supports all stages of the mathematical modeling process:

- **Designing Mathematical Models:** From MS-WORD (the "natural technology" for writing algebraic formulation) the mathematical modeler can obtain computer programs in multiple optimization technologies (like C ANSI, GAMS, IBM OPL, XPRESS/MOSEL, AMPL, AIMMS, among others) without carrying out programming activities.
- **Large-Scale Optimization Algorithms:** Only by "filling the blanks" and activating checkbox controls the modeler can generate programs based on large-scale optimization methodologies. This includes the automatic generation of stochastic programming models.
- **Information Systems:** As part of the implementation process OPTEX handles the automatic generation of a common data- model that allows the off-line integration of all models. Additionally, without programming tasks, OPTEX generates the screens for data manipulation.
- **Mathematical Models Store:** Based on the vision of mathematical models as a collection of objects, the modelers can develop their own "equation store" from which they can build (as a LEGO process) multiple problems that are used to build the models that integrate the enterprise decision support system.

- Artificial Hypothalamus: OPTEX generates automatically, following the business rules and the modeler rules, artificial hypothalamuses algorithms to support Autonomous Real-Time Distributed Optimization (ARTDO).

Los principios conceptuales bajo los cuales se ha desarrollado OPTEX son:

- Optimization Information Systems (the components of the model are stored in tables of an optimization information system). As any relational information its management is organized, standardized and normalized. This ensures control of models developed for companies.
- Optimization Expert System:
  - Capture of knowledge and experience that store the mathematical components that work correctly in the information system, so that it is not necessary to rewrite them. The mathematical model is built as a "LEGO" selecting the proper components (the constraints).
  - Capture the knowledge of a series of runs using:
    - Benders cutting planes that constraint the optimal-feasible zone based on previous runs of a model
    - Optimal convex hull that resumes the optimum response of the complex components of a system, making the model more "light".
- Robotization: OPTEX writes programs ("millions" of instructions of source code) free of errors in the optimization technology selected by the user. This means shorter development times; changes to a model that works properly are implemented in minutes/hours.
- Freedom: OPTEX approach frees the mathematical model (algebraic formulation) of the optimization software, which is directly related to optimization technology like GAMS, AMPL, GMPL, ILOG OPL, MOSEL, C++, R, PYTHON, ….
- Easy to Use: complex models, using large-scale technologies, may be developed in MS-EXCEL or MS-WORD, filling templates.

At the level of the algorithms, OPTEX is oriented to parallel optimization to make use of the computational power that computer technology offers today. OPTEX generates the following types of algorithms without the mathematical modeler having to participate in this process:

- Large Scale Oriented: OPTEX can write models to be solved using large scale partition and decomposition methodologies, like Benders & Lagrangean Relaxation & Cross Decomposition.
- Benders Theory: OPTEX incorporates the "main" variation of Benders Theory (Generalized Benders Decomposition, Combinatorial Benders Cuts, Strongest cuts, Nested Benders, and so on). The implementation of Benders' Theory is parametrized, it implies that the user can selected (customize) the enhancements of Benders that she/he considered convenient (the options are based in extended bibliographical research of real applications using Benders).
- Dual Models: OPTEX writes the models (primal and/or dual) and applied the enhancements or variations of the technologies.
- Dynamic Modeling: for Dynamic Systems, DecisionWare developed the GDDP (Generalized Dual Dynamic Programing) methodology that speed-up the dynamic Benders applications; Dynamic Benders modeling, from 1969, it is based on the concept of L-Shape linear models (known as Nested Benders). GDDP is applicable to any dynamic model (LP, MIP, NLP, MINLP, NLP).
- Cutting Planes Management: Automatic generation and management of databases of solutions (primal & dual) to generate cutting planes to warm up the repetitive models and speed-up their solution.
- Convex-Hull Management: OPTEX facilitates the solution of complex models in which it is necessary to replace some equations of the system, by convex-hull that represent them operating under optimal conditions.
- Parallel Optimization: Automatic generation of statements for parallel optimization (asynchronous or synchronous).

This approach implies that a modeler can change the solution methodology of large-scale models according to results, in minutes.

Using OPTEX the mathematical modelers can think the model and OPTEX will make the software and guarantees the portability of the mathematical models between optimization technologies.

Cognitive Robots Making Algorithms to Solve Large-Scale Mathematical Problems

TRADITIONAL WAY

COMPUTER PROGRAMMERS

OPTEX WAY

COGNITIVE ROBOT

More information in:

- OPTEX Optimization Expert System. The New Approach to Make High Complexity Large-Scale Mathematical Models (Slides Presentation): http://doanalytics.net/RCADT/RCADT-OPTEX-Vision-General.pdf
- Artificial Hypothalamus: Artificial Intelligence and Mathematical Programming Integration. Paper SSRN: https://ssrn.com/abstract=3767763
- Artificial Hypothalamus: Artificial Intelligence and Mathematical Programming Integration. Video: https://youtu.be/tqMm6svjnPY
- The Emperor's Artificial Mind. http://www.doanalytics.net/RCADT/SSRN-Artificial-Augmented-Intelligence&Artificial-Hypothalamus-English.pdf
- The Future of Mathematical Programming presents the future of OPTEX (2020): https://www.linkedin.com/pulse/future-mathematical-programming-jesus-velasquez/

1.1. "MATHEMATICAL" INTELLIGENCE IN INDUSTRY 4.0

INDUSTRY 4.0 gives rise to "smart factories" in which a Cyber-Physical System (CPS) controls physical systems through algorithms based on advanced analytics and tightly integrated over the Internet. In CPSs, physical components and algorithms are deeply intertwined, each element operating at different space-time scales, exhibiting multiple behaviors, and interacting with each other in countless ways that change according to the dynamics of the context.

The best-known examples of CPS are physical systems that use state-of-the-art technologies (e.g., smart grids, integrated autonomous car systems, ...); however, there are also human organizations that base their decisions on mathematical optimization models (planning departments, programming and control centers, boards of directors, technical committees, ...) and that today could be controlled by an "Artificial Hypothalamus" that coordinates, in real time and autonomously, multiple advanced analytical algorithms. This is like the technological evolution, and logic, of the current decision support systems (DSS) moved by humans. This new form of management can be called ORGANIZATION 4.0 and it is based on the concepts of "Enterprise-Wide Optimization".

New technologies and the large amount of permanently generated data (bigdata) change from traditional optimization based on periodic moments, to Autonomous Real-Time Distributed Optimization (ARTDO).

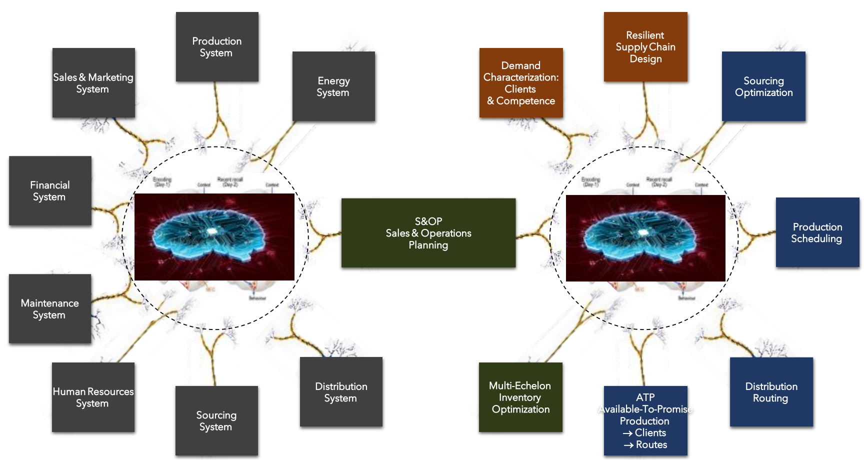
In ARTDO the models are executed autonomously, when necessary, by events. This implies that each component of the system (agent, robot, algorithm, "super-neuron") needs to know what information it must take from smart metering systems, and what information it must provide, so that other agents make their decisions, using asynchronous parallel optimization methodologies, keeping the system (the organization), from end to end, on the "path of optimality". The memory of the system stores in an artificial hippocampus, an SEO.

Augmented Artificial Intelligence (integrated by Artificial Hypothalamus and Artificial Hippocampus) is an integral part of the top two levels of Advanced Analytics: Sparse Distributed Analytics and Cognitive Analytics that rely on the study of the functioning of the human brain to produce increasingly autonomous, more expert, highly automated intelligences that become more "mathematically intelligent" over time in real-world environments.

Below is the vision of the state of the art of AI and mathematical modeling of high complexity, which are summarized in the research and technological development and innovation (R&D+i) that the RCADT is carrying out in the creation of Artificial Hypothalamus (HA) for companies as part of Augmented Artificial Intelligence.

The scientific mission of RCADT is to develop the methodologies and technologies that facilitate the implementation of Artificial Hypothalamuses to support Autonomous Real-Time Distributed Optimization (ARTDO) concept of Industry 4.0. This to facilitate organizations, public or private, control and increase their productivity, which must convert into greater social welfare.

Enterprise-Wide Artificial Hypothalamus



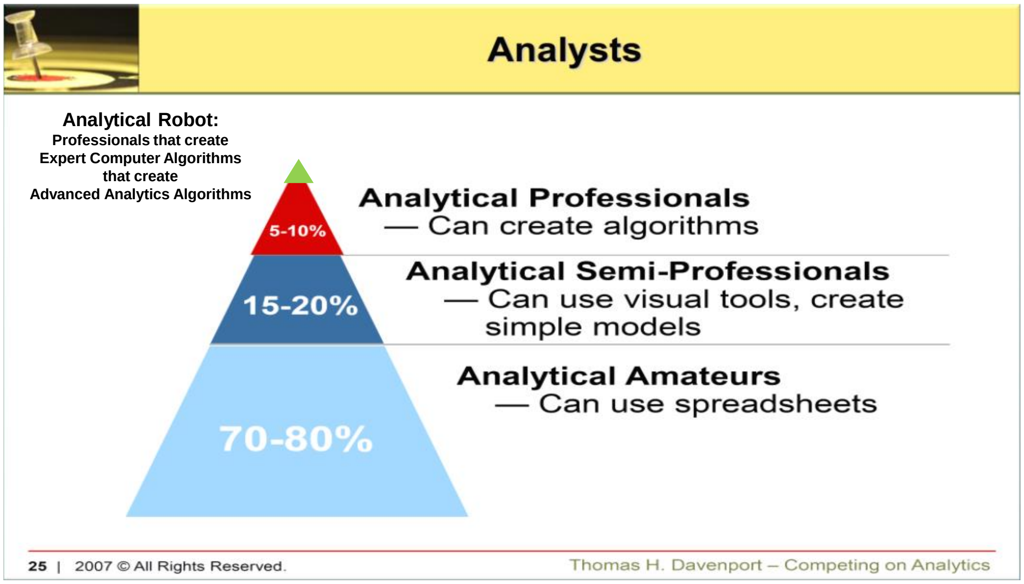
1.2. ADVANCED ANALYTICS PROFESSIONALS

Consistent with the development of the Artificial Intelligence, Automation has come to stay, to the field of the Advanced Analytics, where analysts and modelers received help of robots to do their job; Tomas Davenport, in his seminal book "Competing on Analytics", displayed three types of professionals involved with Analytics:

i) Amateur,
ii) Semi-professional and
iii) Professional

Twelve years after the publication of "Competing on Analytics", comes a new type of professional: the "accelerate professional" that make algorithms using cognitive robots, like OPTEX, which, in turn, make advanced analytical algorithms.

This speed-up the process of use of Advanced Analytics for those organizations that believe in it, and therefore opening more gap with those who do not believe.



1.3. INDUSTRY 4.0 REVOLUTION

Industry 4.0 is a name given to the current trend of automation and data exchange in manufacturing technologies. It includes cyber-physical systems, the Internet of things, cloud computing and cognitive computing. Industry 4.0 is commonly referred to as the fourth industrial revolution. Industry 4.0 fosters what has been called a "smart factory". Within modular structured smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world, and make decentralized decisions. Over the Internet of Things, cyber-physical systems communicate and cooperate with each other and with humans in real-time both internally and across organizational services offered and used by participants of the value chain. (Wikipedia).

OPTEX Optimization Expert System is a robot, based on concepts of Artificial Intelligence, that writes advanced analytics algorithms that are required for the digital transformation of enterprises, OPTEX automatically linking them to the enterprise information system; in summary, OPTEX is a skilled robot that creates robots for complex processes using advanced mathematical methodologies (state-of-the-art). This robotization process is at the highest level of automation because it does not replace manual human work but supports the construction of robots replacing human cognitive tasks, related to the modeling of stochastic processes or business/industrial processes optimization. OPTEX is result of praxis, since it has been used in several industrial/commercial projects that give rise to practices included in OPTEX.

OPTEX increases productivity of mathematical modeler; understanding productivity such as: make more models in less time, ensuring the quality of the produced algorithms. For this purpose, the process of mathematical modeling has been normalized and standardized, this makes OPTEX independent of industrial mathematical technologies. As well as in the manual work robots enhance human ability, in the cognitive process, robots promote knowledge, systematized all tasks that are repetitive.

The cognitive robots are fundamentals for Industry 4.0.

1.4. A NEW APPROACH TO MAKE LARGE-SCALE MATHEMATICAL MODELS

OPTEX reduces to the minimum the cost of developing mathematical models; proposes a new way to implement optimization software, which traditionally involves the implementation of one "executable" program for each model. Since its birth in 1991, OPTEX is conceived as a meta-tool (a robot, an expert system) that allows the development of "all" mathematical models required in just one work environment. OPTEX "automatically" integrates information support system, generating a generic user interface that allow you to browse the tables of the information system. Last, but most important, OPTEX can generate models based on low-level programs such as C, or high-level programs based on algebraic languages like GAMS, AIMMS, IBM ILOG OPL, ... OPTEX ensures minimum implementation times, competitive computing times and portability of the mathematical models. OPTEX make intensive use of large-scale methodologies, like Benders Decomposition.

Using OPTEX, the algebraic formulation of mathematical models is stored in a relational information system, MMIS (Mathematical Models Information System), and therefore the tables that compose the MMIS can be loaded by any mechanism valid for manipulating tables, including EXCEL, while keeping the advantages of relational databases. For this reason, RCADT has developed OPTEX-EXCEL-MMS that enables modelers, non-experts in optimization technologies or without knowledge of SQL (Structured Query Language), to solve complex mathematical problems associated with the database.

As part of the MMIS the modeler must develop the "data model", tables that should fill the end-user. This system, called IDIS (Industrial Data Information System), can reside on DBF tables, EXCEL books, CSV files or any SQL server data type (ORACLE, DB2, SQL Server, MySQL, ...).

One of the advantages of separate the algebraic formulation from the optimization technology is that the modeler is not required to know the syntax of the optimization technology to implement the mathematical model, instead focusing his efforts on the algebraic formulation and complete records of the tables in accordance with given instructions (filling forms/templates). The generated code is error-free, it is the result of many experiences that ensure quality and proper operation; the modeler can learn from the code generated by OPTEX

After formulating the mathematical model, the user has two choices:

i) To load the tables in the data base MMIS or
ii) To maintain EXCEL formulation and control the execution from the OPTEX-EXCEL-MMS interface or from the OPTEX web interface.

In any case, OPTEX is responsible for generating the algorithm program for the associated model.

One of the biggest advantages of this approach is that it minimizes the time of development of mathematical models that can be implemented quickly, by expert mathematical modelers that do not require deeper knowledge in: i) programming optimization languages, ii) large scale optimization methodologies, iii) SQL statements to connect databases and iv) programing languages to make data displays; converting the time saved in avoided cost.

This makes of OPTEX a fast-computing meta-platform oriented to the design, implementation, start-up, and maintenance of DSSs based on a philosophy of concurrent development, in real time. Therefore, reducing the development work of computer programs to a minimum (maybe "zero"). It translates into the immediate availability of additions and/or changes in the models, then the time can be used more effectively in the mathematical modeling process and in the design of the interface DSSs with other tools of the user organization, as may be the BI, ERP, WMS, …

OPTEX supports all activities required to implement "real-life" solutions, the process to follow for each mathematical model can be summarized in the following steps:

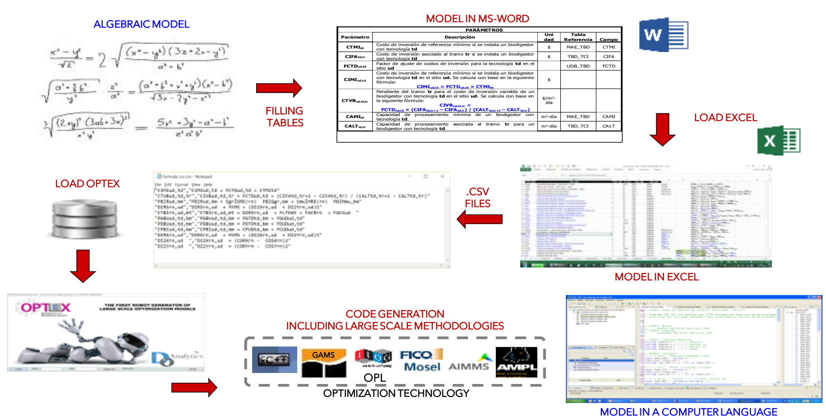
1. Mathematical modeling, whose product is a conceptual algebraic model.
2. Data Modeling, whose product is the data model of an information system.
3. Automatic implementation of the information system.

4. Generation of optimization programs that are capable of generate the numerical problems.
5. Solving the problem using numerical algorithms specialized in accordance with the format of the problem.
6. Storage solution in the information system; and
7. Query and routing the results of the model.

The following diagram shows the process working based on Microsoft (MS) software:
i) Algebraic model in the blackboard,
ii) Algebraic formulation in templates in MS-WORD,
iii) Algebraic formulation in tables in MS-EXCEL,
iv) Algebraic formulation in CSV format in ANSI standard,
v) Import the csv files to OPTEX-MMIS,
vi) Computer algorithm of the model in an optimization technology.

The mathematical modeler can summarize the above process by converting algebraic equations directly into elements of the OPTEX database.

DEVELOPING MATH MODELS - OPTEX FLOW CHART



1.5. OPTEX DECISION SUPPORT SYSTEMS

The document http://doanalytics.net/HAI/HAI-Experience-Full.pdf contains "all" models that has been design, implement and/or use based on OPTEX.

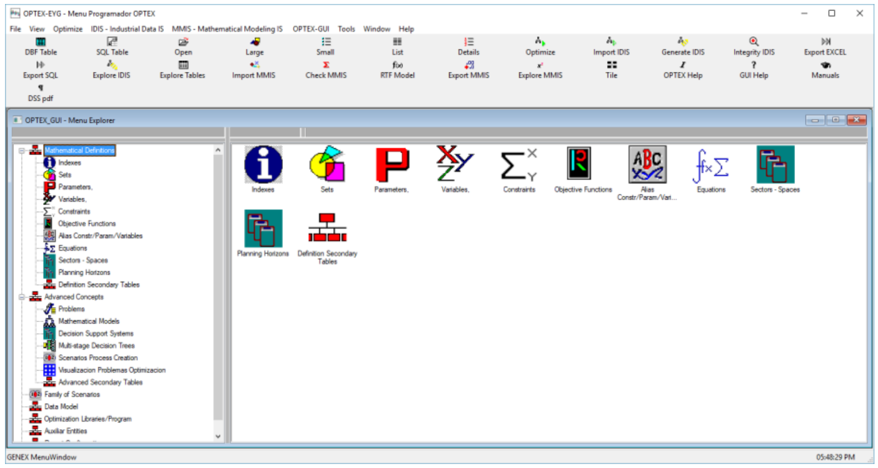
2. STRUCTURED MATHEMATICAL MODELING

Sort the elements that are part of a mathematical model around the concepts of information systems involves the need to structure the process of mathematical modeling in a way to store all elements in the tables of the MMIS; this implies organize the mathematical model from an "universal" point of view such as an information system; then, it is possible to affirm that the information system that supports mathematical modeling in OPTEX is the first step towards standardization and normalization of the algebraic formulation of mathematical models, which is needed to socialize the Mathematical Programming based in the portability of the models between optimization technologies.

2.1. MMIS - MATHEMATICAL MODELING INFORMATION SYSTEM

The MMIS manages the following elements (objects, entities):

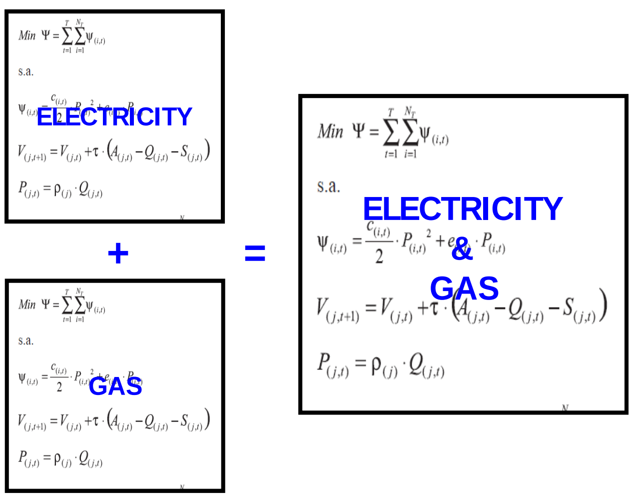
- Tables
- Fields
- Indexes
- Sets
- Variables
- Parameters
- Restrictions
- Equations
- Objective Functions
- Problems
- Models
- Decision Support Systems
- Application



From the above objects, four haven't a universal definition:

- Problem: set of constraints.
- Model: set of problems.
- DSS: set of models; and
- Application: set of DSSs.

MMIS standardizes the management of entities and relationships centered about its database algebraic language that allows management of linear and non-linear equations.



The above objects are critical to addressing large-scale problems by coordinating multi-problem models; OPTEX is based on the vision that sees the Mathematical Programming as a standard that can be understood by any expert modeler, this standardization is so solid that ensures that the binding of Mathematical Programming problems is a new problem of Mathematical Programming. OPTEX capitalized this advantage as the union/partition of two problems correspond to union/partition of the restrictions of the two problems, which is performed based on tables that store the parameterization of the problems and not based on the union of two computer programs, which it is more difficult, may be impossible, to standardize. For example, an integrated model of the electricity-gas system is the union of the equations of the two individual systems (gas & electricity) plus the coordination constraints.

The MMIS handles all aspects of the formulation, the solution, and the use of mathematical models. Conceptually, OPTEX groups information according to the steps that must be faced in the process of developing an application:

i) Formulation of mathematical definitions.
ii) Formulation and solution of problems and models.
iii) Optimization connectivity libraries.
iv) Using models

2.2. SOLVING OPTIMIZATION PROBLEMS

The formats of problems that can be solved with OPTEX dependent of optimization libraries that are available to the end-user, making it possible to formulate linear or non-linear models (LP, MIP, QP, QPQC, MECP, NLP,...).

In addition to solving the basic optimization problems, OPTEX includes several advanced services, for real-world problems, aimed at facilitating the implementation of large problems. Among the services offered OPTEX generates models that includes:

- Variables for feasibility analysis.
- Initial pre-set value for any variable.
- Equations for re-optimization including fixed variables.
- Convex hull generation.
- Generation of multi-criteria Pareto efficiency frontiers
- Parallel/Distribute optimization of multi-problem models.
- Disjunctive optimization
- Large-scale optimization methodologies

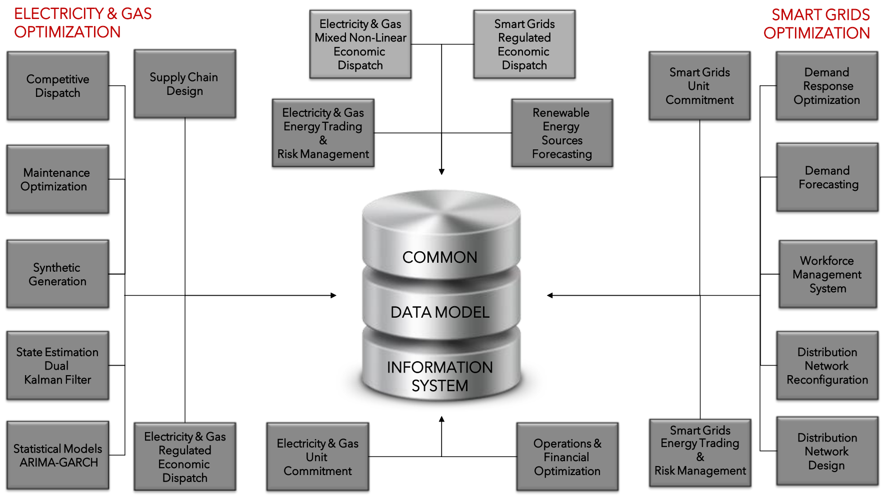
2.3. INTEGRATION OF MULTIPLE MODELS AND PROBLEMS

Due to the complexity of real systems, DSSs are composed of multiple mathematical models which are integrated through the data stream, thereby generating the information required by the decision maker to address all hierarchic levels: strategy, tactic, operation, and real-time operations. The connection of data and models defines the decision-making chain, which supports management productivity of organizations.

The different models must share information stored on a common database, coherent and standardized, to allow data integration along the decision-making chain, in which some of the outputs of a model becomes the inputs of the models of subsequent stages, so this coordinated effort guarantees "optimization" of the entire system, it is impossible to obtain with a single model. Researchers and producers of technology solutions share this point of view.

The concept of objects allows an OPTEX problem being part of several models and a restriction to be part of various problems and so on. This approach facilitates the handling of large-scale optimization models; since under the partition and decomposition scheme, a model consists of several coordinated problems whose solution is performed in accordance with an optimization methodology like Bender Theory or Lagrangean Coordination.

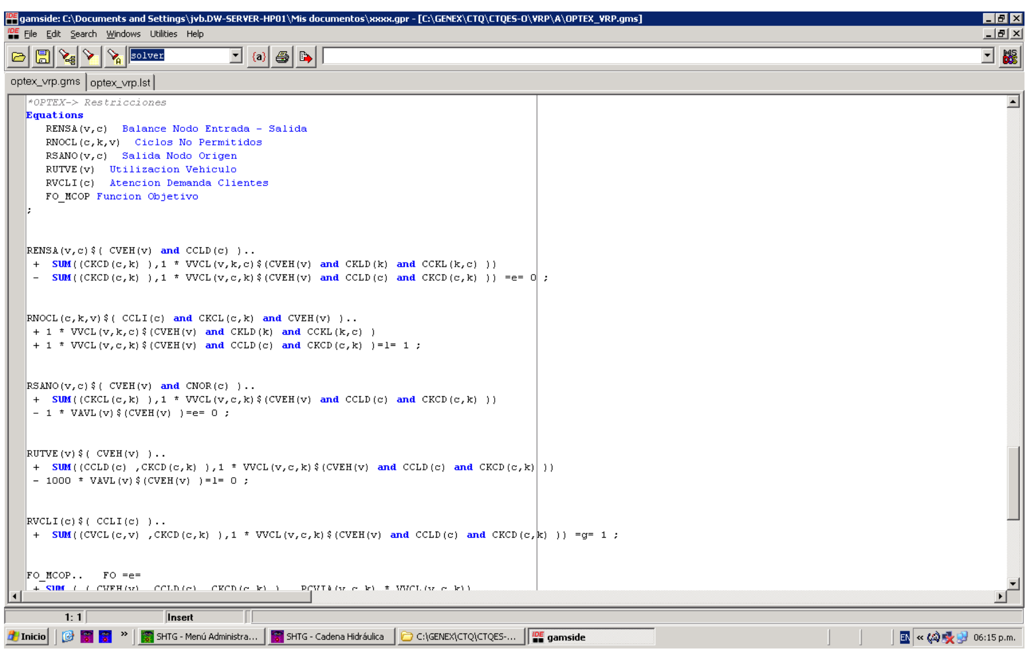
The next diagram shows the integration of models of an DSS for the electric sector.



2.4. PROGRAM CODE GENERATION

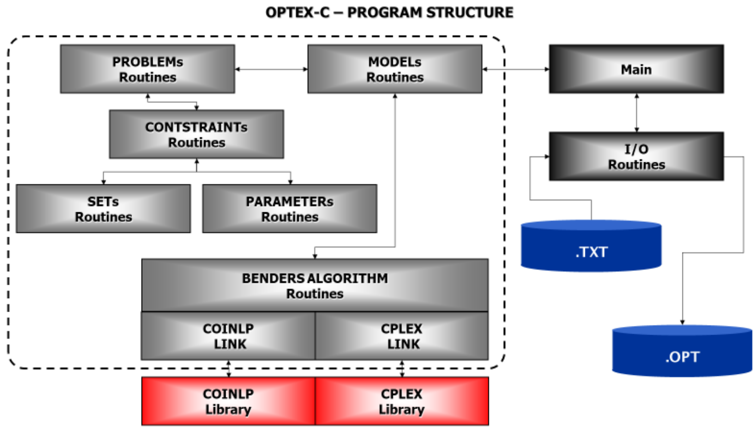
OPTEX generates programs of mathematical models in high-level algebraic languages, like GAMS, IBM ILOG OPL, MOSEL, AIMMS, AMPL, …, and in languages of general purpose like C and PYTHON (in development), making it in a generic meta-platform that works as interface for multiple Mathematical Programming technologies that do not support services offered by OPTEX.

For example, with GAMS; OPTEX facilitates to the user the connectivity between mathematical models and information system, aspect that is not explicitly considered in GAMS; in this way the modeler can generate GAMS programs including SQL connectivity with the information system of the end-user.



The C ANSI program generation allows to develop applications based on complex process of interconnection models, which can be personalized according with specific characteristics of end-user, indispensable requirement when it comes to operative solutions for industrial processes and product and/or person distribution.

The diagram presents the C program structure.

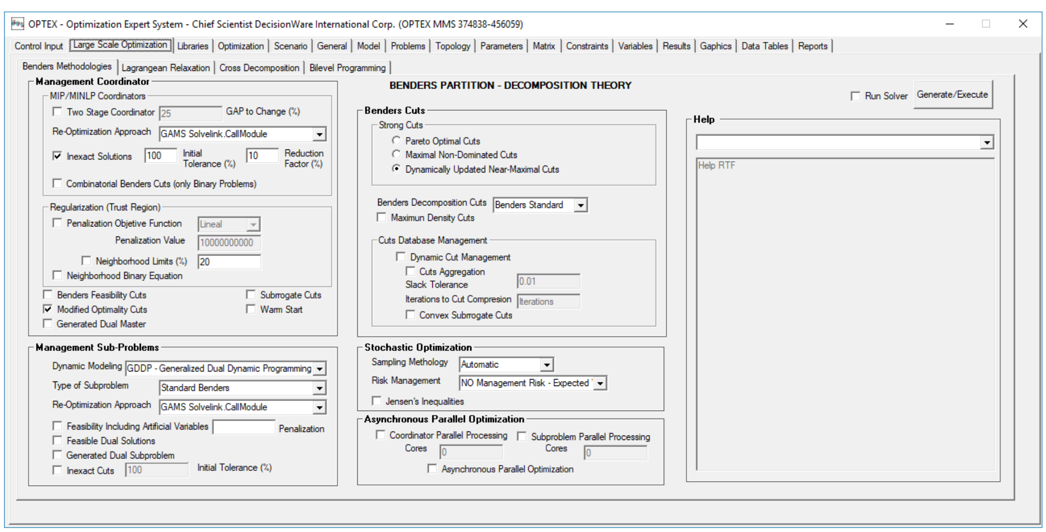


2.5. LARGE SCALE & STOCHASTIC OPTIMIZATION

The concept of multi-problem model facilitates the implementation of Large-Scale Optimization Methodologies (LSOM) based on multi-level partition and decomposition, using Bender's Theory and/or Lagrangean Relaxation. RCADT algorithmic developments are concentrated in large-scale methodologies rather than the solution of basic problems. Focusing its research effort in generating effective computational codes to resolve such problems by making use of the advantages that today offer computers with multiple CPUs and computer grids. Thus, the no-expert modeler in this type of technology can access them in multiple computing technologies.

Considering that large scale technologies are the necessary complement to the basic optimization solvers (IBM CPLEX, GUROBI, XPRESS, …), since the union of the two powers allow to solve larger and more complex mathematical problems, OPTEX incorporated as part of its services the automatic generation of computer algorithms using the variations and the improvements that have been developed by researchers.

The screen allows the parameterization of a model using the Benders Theory so that the user can research to determine what methodology can be called the "best" for its specific problem. OPTEX includes various variations of the basic theory like Generalized Benders Decomposition (GDP), Dual Benders Decomposition (DBD), Nested Benders Decomposition (NBD) and others.



For dynamic systems, OPTEX includes the GDDP (Generalized Dual Dynamic Programming) a large-scale methodology developed by RCADT for speed-up the solution time of large dynamic models compared with NBD which is based on the concept of L-Shape linear models. GDDP is applicable to any convex dynamic model (LP, MIP, NLP, MINLP, NLP) and "some" non-convex models. The first version of GDDP was implemented in 1991; the first publication, in a Scientific Journal, in 2002. https://www.linkedin.com/pulse/stochastic-dynamic-benders-theory-jesus-velasquez/

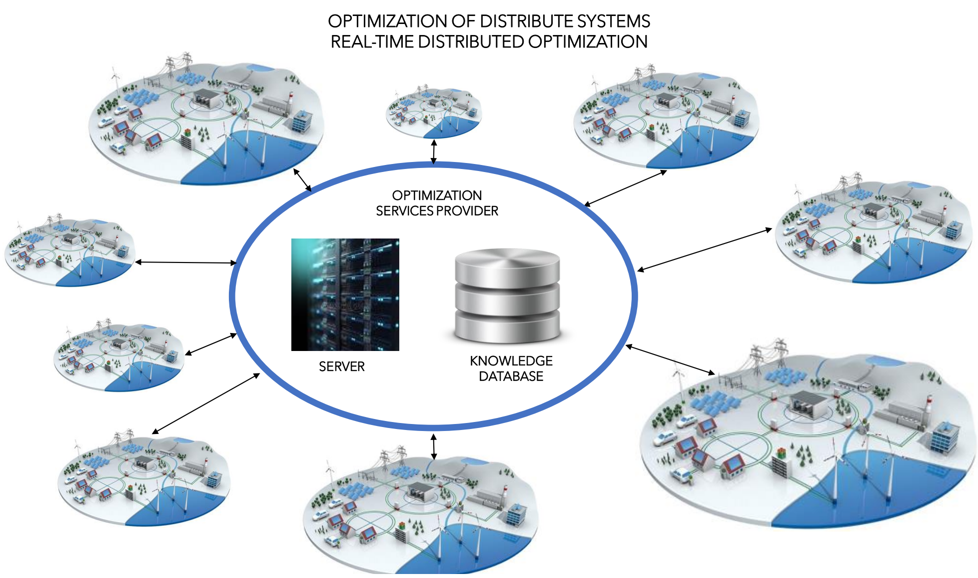
OPTEX includes as part of their services the modeling of Multi-Stage Stochastic Programming (MS-SP) that implies to handle random processes over the decision trees and solve problems with different types of objective functions, for example: i) expected value; ii) MiniMax or Maximin and iii) maximum regret; additionally, OPTEX includes several alternative to risk management, including conditional-value-at-risk constraints (CVaR).

The conversion of deterministic (core) model to stochastic models is automatic, in the sense that the user must only configure the conversion process and OPTEX generates the stochastic model from the deterministic formulation. The problems are generated using "split" variables with non-anticipative constraints. The uncertainty dimensions may be defined by the users, considering which are the more convenient considering the type of model and dynamic of the stochastics process. The solution of these problems can be accomplished through direct solution of equivalent deterministic problem or using large scale optimization methodologies. Sampling methods may be included in the algorithms.

2.6. PARALLEL & DISTRIBUTED OPTIMIZATION

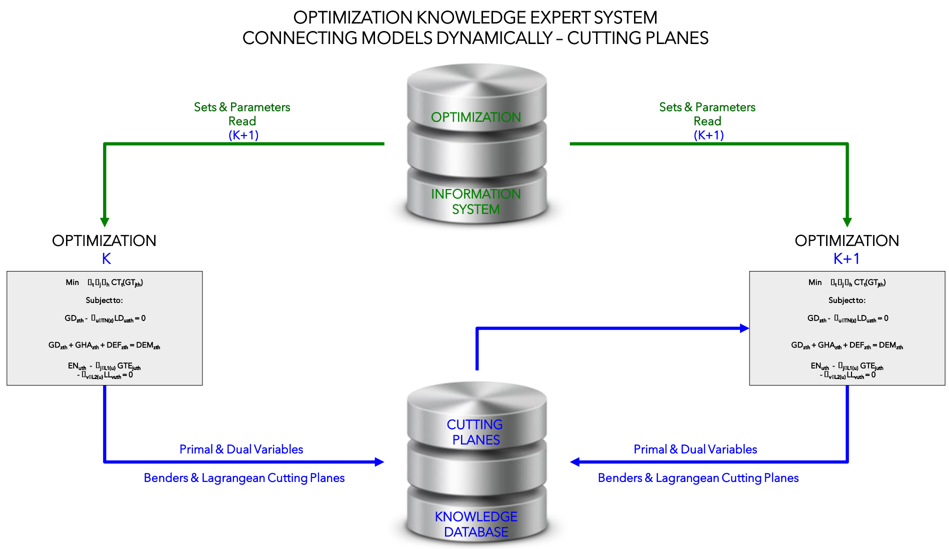
In the future, the real-life solution based on Mathematical Programing, applied to large physical and social structures/organizations, must be based on multilevel parallelism using the modern computational architectures then, Large Scale Optimization Methodologies (LSOM) are the fundamental to atomize an optimization/equilibrium mathematical problem in multiple types of sub-problems that can be solve using the concepts of:

i) Asynchronous Parallel Optimization (APO) (solving complex model using parallelization): defined as the solution of a large problem using the multiple cores of a workstation/server and/or a grid of computers;
ii) Autonomous Real-Time Distributed Optimization (ART-DO): defined as the solution of a problem in which multiple agents work coordinately to permanently keep the system on the optimality path; an example is the optimization of the energy smart grids.

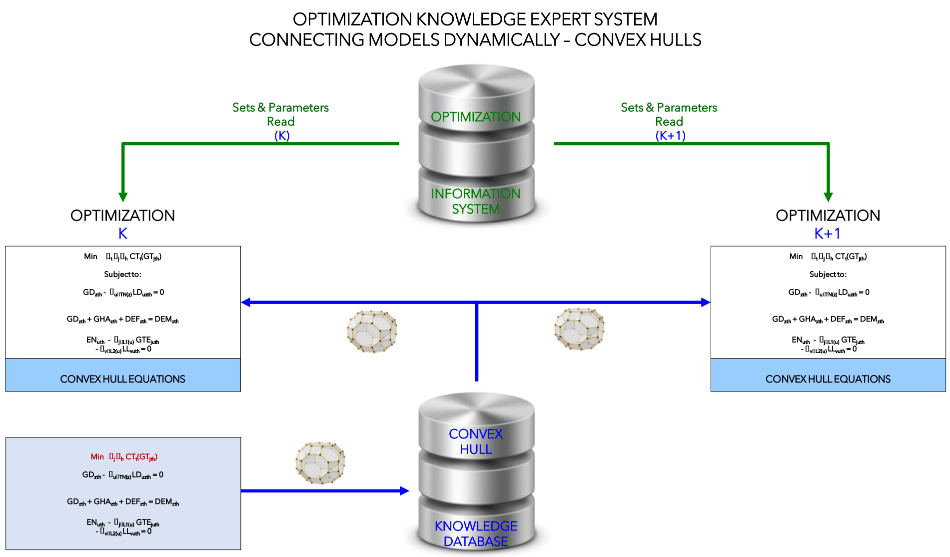


To implement the previous processes, mainly RT-DO, the management of multiple solutions of atomized-problems is necessary; this implies to introduce the concept of optimization expert systems oriented to:

- Knowledge Accumulation that exists in the multiple's solutions of problems. An example is to use the Benders cutting planes of a run (k) in the next runs (k+1, k+2, ...). The management of databases of solutions (primal & dual) can be used to warm up the repetitive models and speed-up their solution. The next diagram describes the situation.

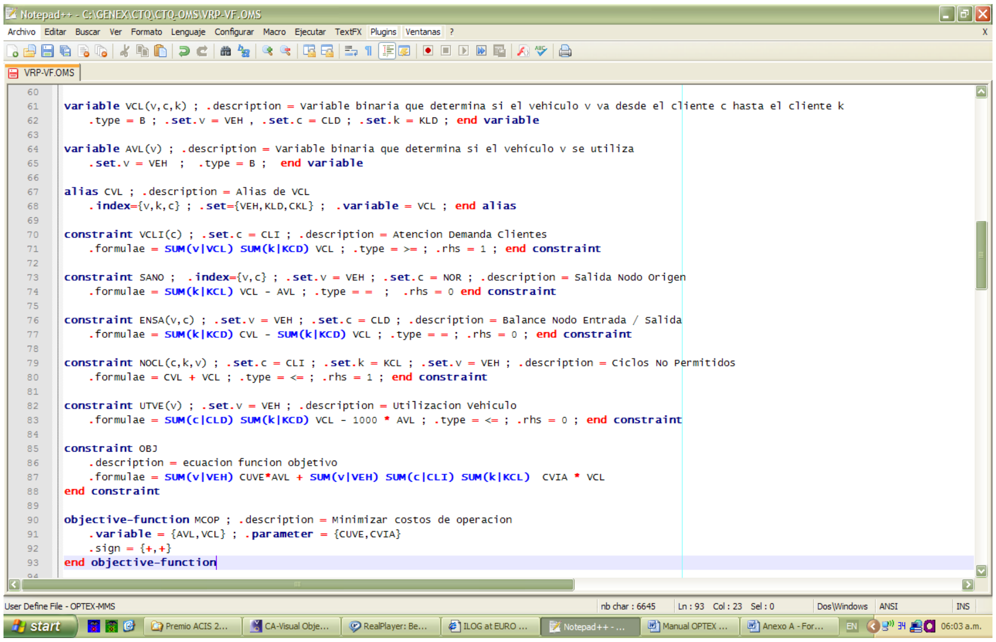


- Knowledge Generation during the idle time of the computers pre-solving the complex part of a large/complex mathematical models. This may be get representing the complex part as follow: i) using the convex-hull of optimal solutions, that may be solved when the computer is idle and ii) including the equations that represent the convex hull (normally a grid) in the integrated model. The next diagram describes the situation.



2.7. OPTEX ALGEBRAIC LANGUAGE

OPTEX has an algebraic programming language, like GAMS or AMPL. The compilation process works in double pass: i) first analyzes the program syntax and ii) second analyzes the logical content of the program; if everything is correct it is linked with OPTEX-EXE. Since from an OPTEX program is possible to fill the tables of MMIS. For programs editions the modeler can use NOTEPAD^{++}, a customized free software.



3. OPTEX PROCESSORS

OPTEX works like an integral system that offers to the modeler a range of possibilities that guarantees efficiency and flexibility to face the implementation process of a decisions support system oriented to be launched in an end-user. The modules that integrate OPTEX are presented below.

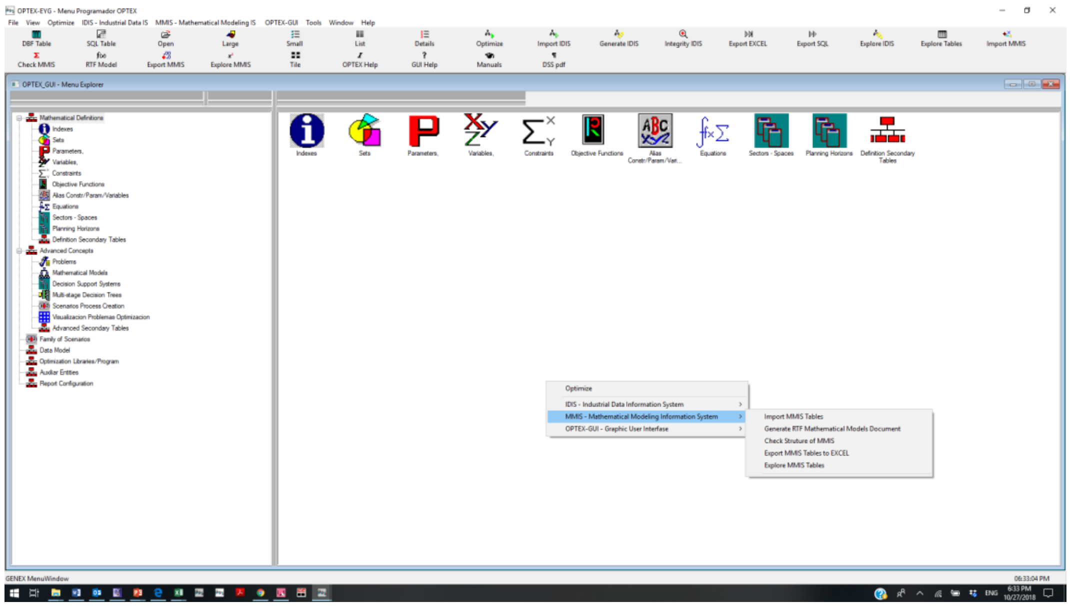
3.1. OPTEX-GUI: INTEGRATED DEVELOPMENT ENVIRONMENT

OPTEX-GUI corresponds to the IDE interface (Integrated Development Environment) used by the modeler and its objective is to facilitate the access to all tables that integrated the DSS, this means MMIS or IDIS.

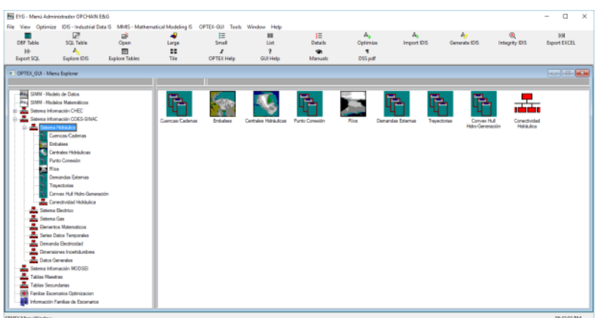
The algebraic formulation stored in databases allows the mathematical modelers to work simultaneously as users of LANs and/or WANs; this is one of the most important characteristics of OPTEX, not possible in the optimization technologies based in computer programs. OPTEX-GUI is a client application that works in MS-WINDOWS available for those who has installed OPTEX in their computers.

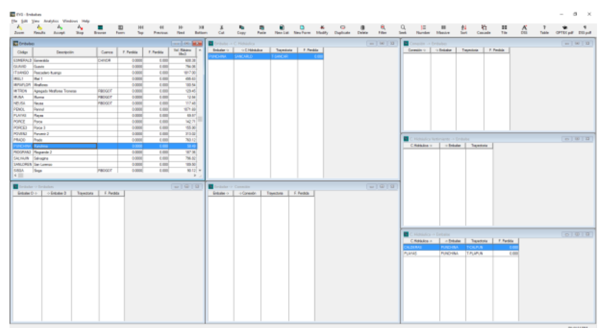
OPTEX-GUI is based on a browser like "windows explorer" that allows the user to access all tables of MMIS and of IDIS; also, it has processes services which can be accessed through menus application. The connection to the tables is performed without programming tasks, in this way the modeler parametrize the way used by the end-user to access to the IDIS tables.

OPTEX-GUI allows to the modeler interact with the MMIS in such a way that he can update the model equations as the changes are required. OPTEX-GUI includes an online help system, providing to the modeler the necessary information about different aspects of the application that is being developed.



The next images show the explore window of final user and the shell window to see a master table and all related tables.

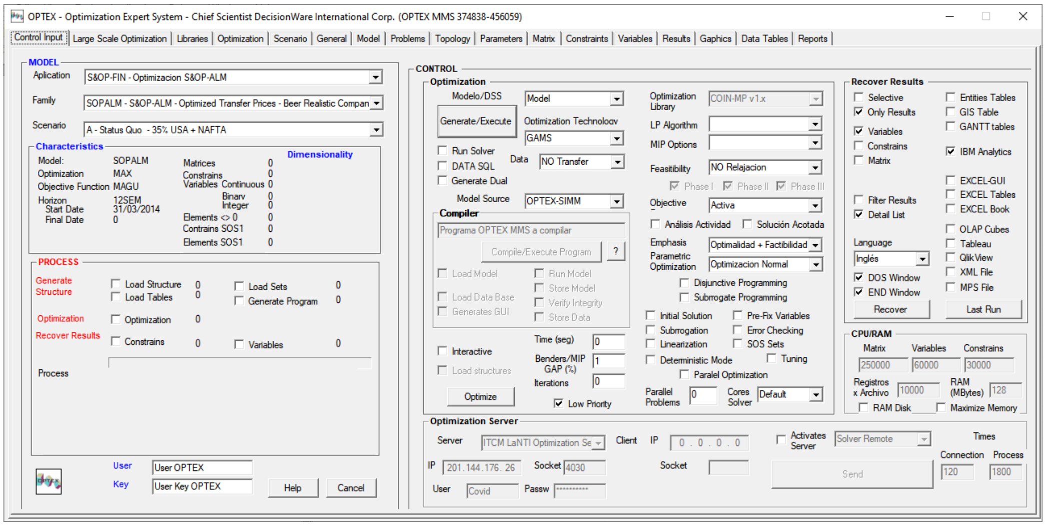




3.2. OPTEX-EXE: INTERACTIVE SOLVER

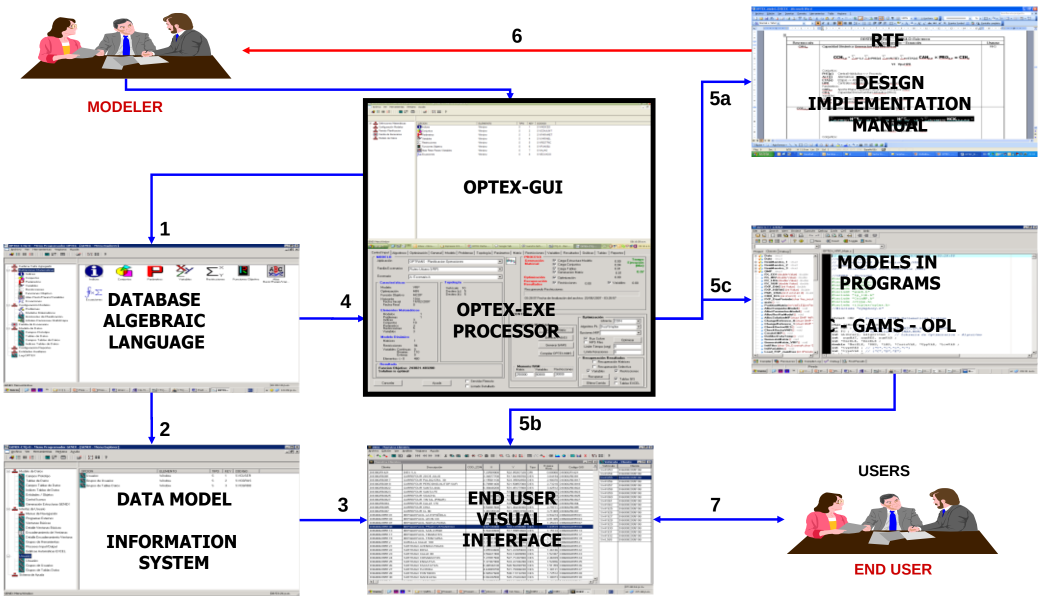
OPTEX-EXE processor is responsible of perform all tasks related to the optimization services offered by OPTEX. OPTEX-EXE has an interactive control interface allowing the modeler to conduct, step by step, the optimization processes; also, it can be executed as a task in the back-end for automatic processing, controlled by a configuration file. This is only available for users with OPTEX installed on their computer. This interface can be activated from OPTEX-GUI, and it works on MS-WINDOWS environments.

OPTEX-EXE is designed to act as client and as optimization server, in this way the implementation of a "cloud" environment solution using a remote server focuses on the implementation of OPTEX-EXE in both computers with its corresponding parameterization.



The next table describes the steps to work with OPTEX-GUI and OPTEX-EXE

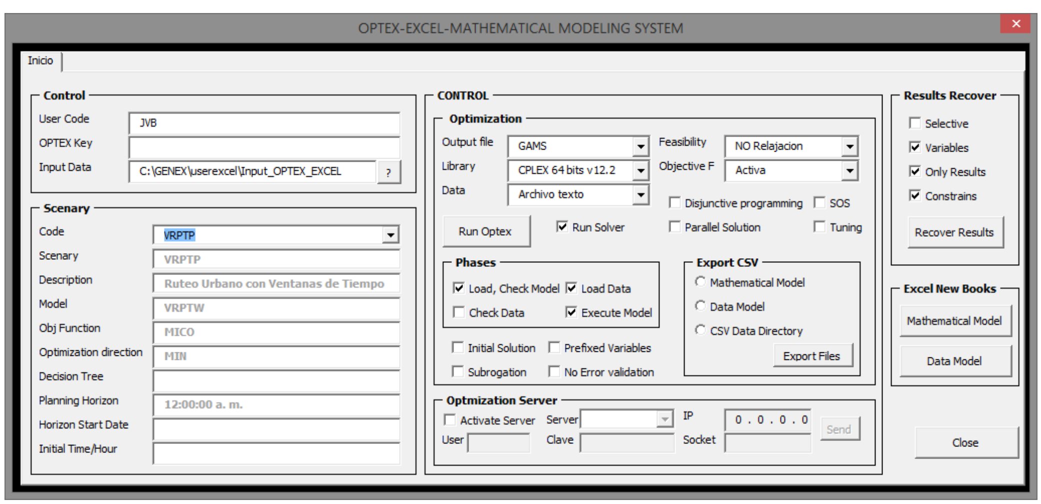
STEPS IN THE IMPLEMENTATION OF OPTEX APPLICATIONS	
STEP	DESCRIPTION
1	ALGEBRAIC MODEL LOAD The process begins with the load of the algebraic model by the responsible administrator/modeler of the model being implemented. This process implies to fill the corresponding database to the MMIS, this process must follow general guidelines describe bellow and it is performed through the access to OPTEX-GUI or to OPTEX-EXCEL-MMS.
2	MODEL DATA LOAD The process of defining the data model of IDIS is a process that is generated simultaneously with the loading of mathematical models so, as relations between the two models are strong so that the table structures are determined by the structure of the mathematical model, primarily by the relation between sets, parameters, variables, and constraints. This process is performed through access to OPTEX-GUI or to OPTEX-EXCEL-MMS.
3	GENERATION OF THE VISUAL USER INTERFACE OPTEX GUI provides services to generate a user interface without programming tasks, this involves organizing the shell windows in tables associated with a main table and the related secondary tables. This query is performed through the administrator who must built menus to provide access to end-users. This process is performed through access to OPTEX-GUI.
4	USING OPTEX-EXE Once the database is loaded into MMIS, the next step is to interact with OPTEX-EXE to begin the process of adjustment of the formulation of algebraic models.
5	ANALYSIS ALGEBRAIC MODEL The analysis of the algebraic model involves interaction coordinating two simultaneous activities: ▪ Review loaded algebraic formulation into MMIS; and ▪ Review the results obtained with the models.
5a	REVIEW ALGEBRAIC MODEL FORMULATION This activity is carried out mainly with the RTF document generated by OPTEX, where the user can see the exact formulation loaded in MMIS and find errors in it and/or the needs for adjustments due to imperfections in modeling.
5b	STORAGE ALGEBRAIC MODEL RESULTS This activity is performed automatically by OPTEX-EXE and/or by the programs generated with OPTEX.
5c	REVIEWING THE RESULTS OF THE ALGEBRAIC MODEL This activity is mainly observing the results produced by the algebraic model that is being implemented as a result, the user can find errors in the data loaded in IDIS and/or the need for adjustments due to imperfections in modeling. This process is performed through access to OPTEX-GUI.
6	SETTING THE ALGEBRAIC MODEL Following the analysis of the development and results in the early stages of implementation, it is necessary to make changes to the MMIS and IDIS. This cyclic process ended when the modeler considers that the implemented model produces the correct results, and it is ready to be delivered to the end-user.
7	DATA ACCESS BY THE END-USER Finally, the end-user can access to use the model, which is made based on the data stored in the IDIS and results generated by the models.



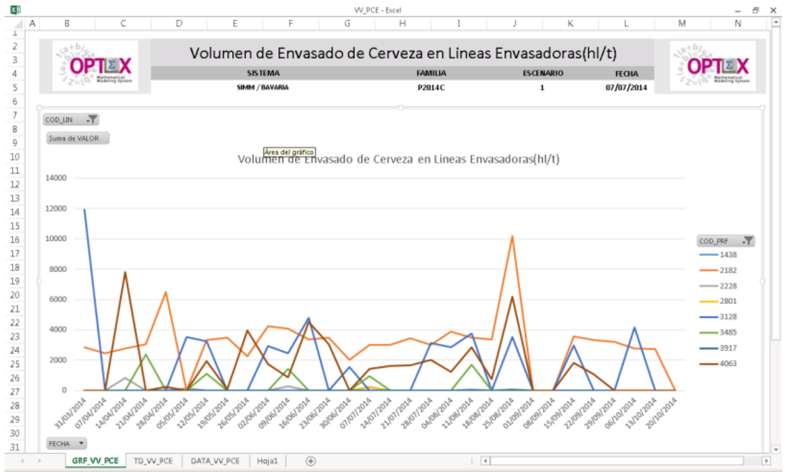
3.3. OPTEX-EXCEL-MMS: EXCEL OPTIMIZATION EXPERT SYSTEM

As already indicated, the data corresponding to the formulation of mathematical models is stored in the MMIS and therefore the information system can be loaded for any valid mechanism for loading database, with EXCEL one of the most popular tools for processing tables.

The advantage of loading the mathematical models through tables is that the modeler does not require to know programming languages to implement the mathematical models. After load the mathematical model in EXCEL, the tables can be loaded into the database OPTEX or kept in EXCEL; in any case OPTEX is responsible for generating the code associated to the programming language that the modeler has selected.

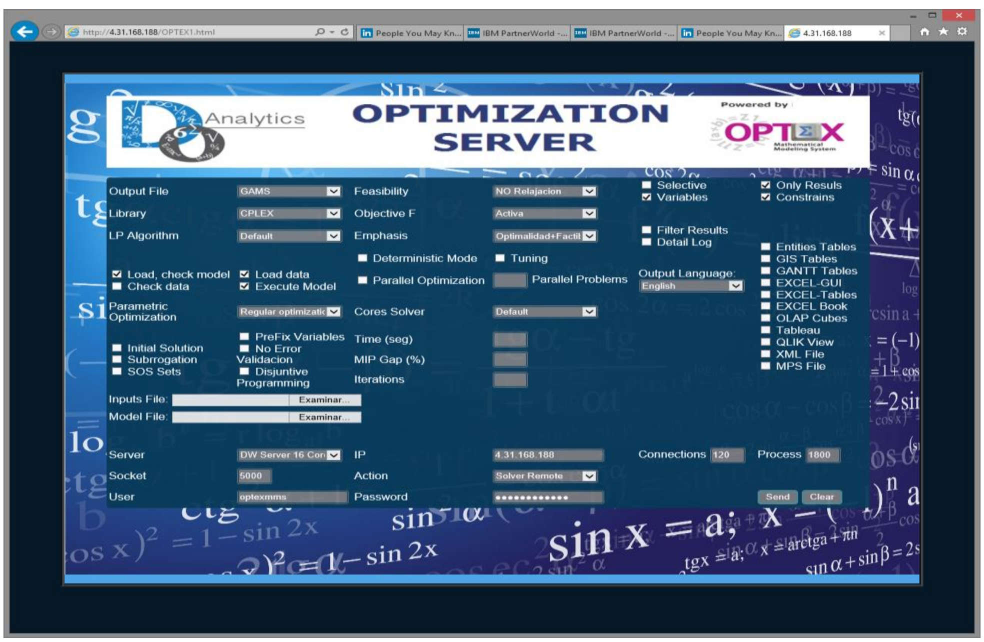


OPTEX-EXCEL-MMS controls the processes to be performed with OPTEX from EXCEL when the user has installed OPTEX on his computer or when the user access to OPTEX optimization server. The process was described previously. The following figure shows the results in the OPTEX-EXCEL-GUI, part OPTEX-EXCEL-MMS.



3.4. OPTEX-WEB: OPTEX WEB ACCESS SERVICE

OPTEX-WEB: Modeler interface oriented to using EXCEL to develop models. Available on a website controlled by RCADT or by an OPTEX user.



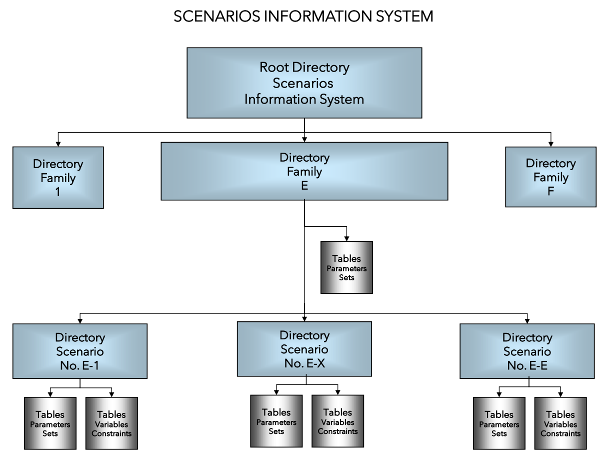
4. IDIS: INDUSTRIAL DATA INFORMATION SYSTEM

The data that represents the technical and socio-economic information of the industrial system are stored in the IDIS, classified into two types:

- IIS: Permanent Industrial Information System, corresponding to the tables of the information system that are independent of any scenario (case study); and
- SIS: Scenarios Information System, corresponding to the tables that represents the variability of scenario.

The IDIS data model depends on mathematical models; the content stored in tables depends on the physical system modelled and on the scenarios that the user wants to analyze. OPTEX-GUI provides services to configure the IDIS data model and its user interface; both IIS and SIS are relational information systems whose data models depend on mathematical models.

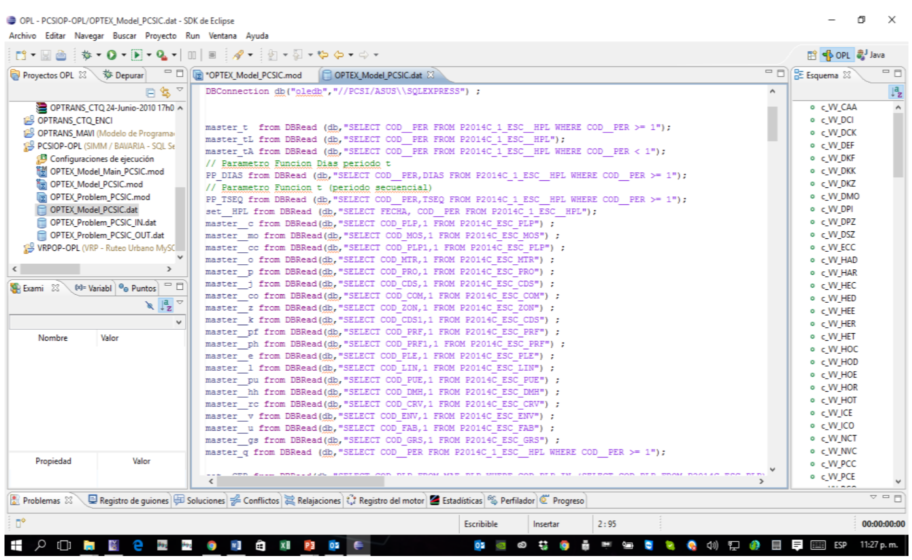
The scenarios are grouped under the concept of scenario families, so that the user can perform cross analysis of all scenarios that belong to a family. SIS corresponds to the union of information systems of each scenario.



OPTEX provides services for the development and implementation of the data model and corresponding user interface; thus, the development of mathematical models of the corresponding system information and the visual interface is limited to a process of filling tables.

4.1. SQL CONNECTIVITY SERVICES

To support the IDIS information system, OPTEX provides connectivity services with tables stored in EXCEL, CSV, DBF and SQL server type, connected via ODBCs (Open DataBase Connectivity). The following picture shows the SQL connection for loading data into an IBM ILOG OPL program



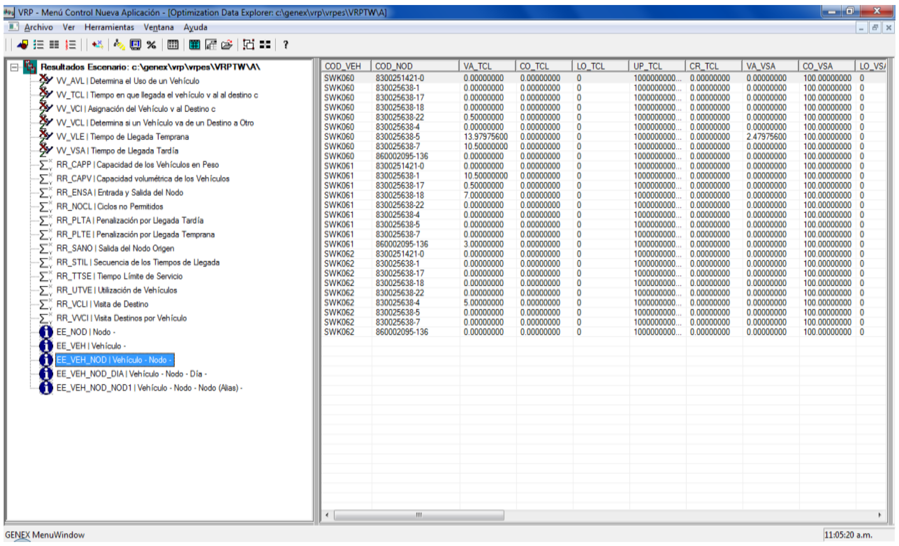
OPTEX provides the following services to support IDIS:

- Structuring the data model
- Generation user interface for access to IDIS tables.
- Check the integrity of the database
- Generation of derived tables for integration between OPTEX models and other computer systems.
- Generation of SQL statements for connection with optimization technologies
- Automatic mapping with other information systems (ERP, WMS, TMS, GIS, ...)
- Import/Export Data
- Structured query of IDIS tables.

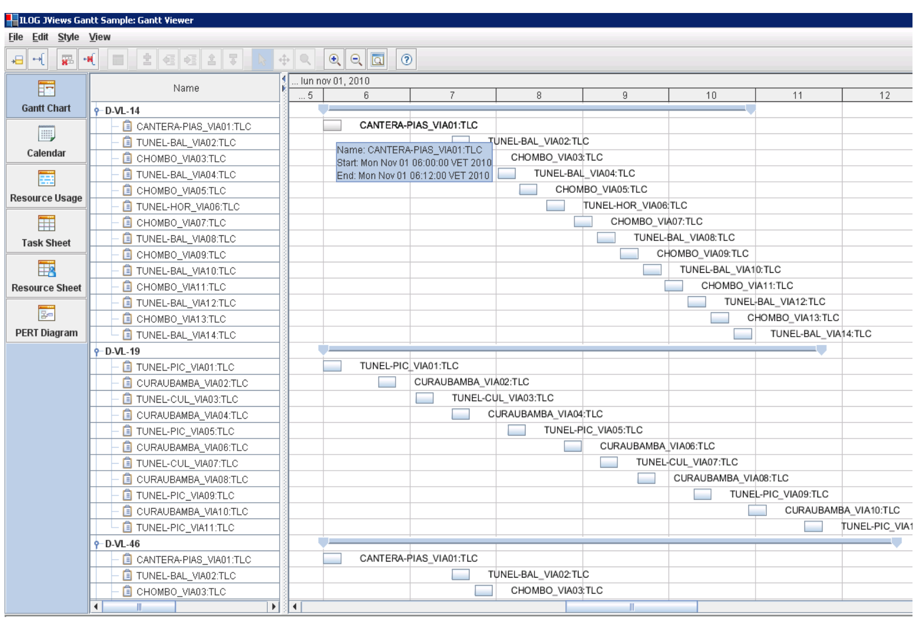
4.2. RESULTS STORE & DISPLAY

In OPTEX -GUI the modeler has access to tables that contains the results of variables and constraints for each specific scenario.

A fundamental part in the implementation of a decision support system is its ability to display the results associated to mathematical models that produce millions of data (big data). OPTEX approach facilitates the linking of results with information technology tools aimed at the exploration and visualization of large data volumes. All results of mathematical models, primary and dual variables, independent of optimization platform. Data is stored in relational tables that can be consulted by the user through OPTEX-GUI.



Based on this approach OPTEX can generate XML interfaces with EXCEL, MS-Project, IBM-Jviews, IBM TM1, TABLEAU, QLIKVIEW and Mondrian OLAP Server. The following image shows an example of displaying a routing program in IBM-Jviews.



5. DOCUMENTATION

OPTEX generates **RTF** documents (**R**ich **T**ext **F**ormat), visible and editable with text editors' programs like **MS-WORD**. The **RTF** contains all the mathematical formulation included in a mathematical model. Thus, it guarantees proper documentation of the implemented models. Following, an example of the generated documentation.

<table>
<tr><th colspan="3">RESTRICTIONS – MODULO:</th></tr>
<tr><th>RESTRICTION</th><th>DESCRIPTION – EQUATION</th><th>DISJUNCTIVE VARIABLE</th></tr>
<tr><td>$BIEV_{t,j,hh}$
DECx1000</td><td>Existencias Máximas de Producto Final más Envase en Centros de Distribución

$$\Sigma_{p\in PT(j)} \Sigma_{v\in PVJ(p\ j)} ICE_{t,j,p,v,hh} + \Sigma_{v\in JV(j)} EVJ_{t,j,v,hh} \leq ACE_j$$
$\forall t \quad \forall j\in PUN \quad \forall hh\in\_DIM\_hh(*)$

Índices:
t Período
j Centro Distribución
hh Escenario Demanda
p Producto
v Envase

Conjuntos:
$p\in PT(j)$ Productos Cerveceros x Centro de Distribución j
$v\in PVJ(p,j)$ Envases x Producto x Centro de Distribución j
$v\in JV(j)$ Envases x Centro de Distribución j
$j\in PUN$ Centros de Distribución (j)
$hh\in\_DIM\_hh(*)$ Dimension hh <- Escenario Aleatorio
Parámetros:
ACE_j Capacidad Almancenamiento del Centro de Distribución (UNDx100)
Variables:
$ICE_{t,j,p,v,hh}$ Existencias de Producto Finalizado en Centros de Distribución (DECx10)
$EVJ_{t,j,v,hh}$ Existencias Envase Vacío en Centros de Distribución (DECx10)</td><td></td></tr>
<tr><td>…</td><td>…</td><td>…</td></tr>
<tr><td>$WHE_{t,l,hh}$
Hrs</td><td>Tiempo Trabajado en Línea de Empacado. NO incluye tiempo preparación Línea

$$HOE_{t,l,hh} + HEE_{t,l,hh} - \Sigma_{p\in LP(l)} \Sigma_{v\in LTV(l\ p)} KWE_{l,v} \times PCE_{t,l,p,v,hh} = 0$$
$\forall t \quad \forall l\in LN \quad \forall hh\in\_DIM\_hh(*)$

Índices:
t Período
l Línea Envasadora
hh Escenario Demanda
p Producto
v Envase
Conjuntos:
$p\in LP(l)$ Productos x Línea de Envase
$v\in LTV(l,p)$ Envases x Línea de Envase x Producto
$l\in LN$ Línea de Envase
$hh\in\_DIM\_hh(*)$ Dimensión hh <- Escenario Aleatorio
Parámetros:
$KWE_{l,v}$ Velocidad de Producción de Línea Envasadora (Hrs/UNDx100)
Variables:
$HOE_{t,l,hh}$ Horas Ordinarias de Producción en Líneas de Envasado (Hrs)
$HEE_{t,l,hh}$ Horas Extras de Producción en Líneas de Envasado (Hrs)
$PCE_{t,l,p,v,hh}$ Volumen de Envasado de Cerveza en Líneas Envasadoras (DECx10)</td><td></td></tr>
</table>

Reports include the description of the data model and the link between the fields of each table and the sets and the parameters of the models that are read as input data.

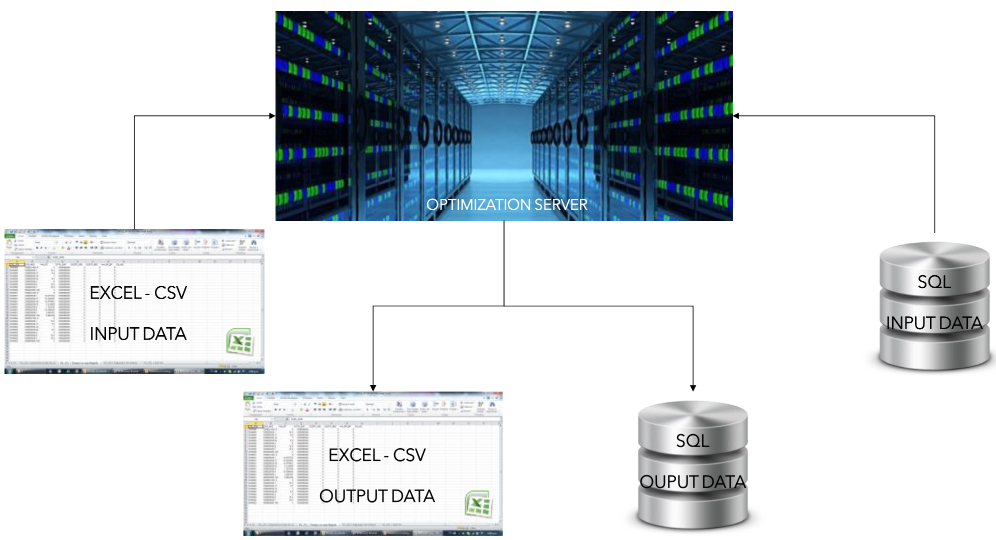
6. OPTEX OPTIMIZATION SERVER

Following the actual trend of cloud solutions, OPTEX allows the development of applications oriented to solve optimization problems, using services provided on the Internet (cloud services). For client-server applications OPTEX considers four roles that interact between them, allowing multiple architectures configured according to user needs:

- OPTEX-GUI: Graphical interface that allows to the administrator and users to view OPTEX information system.
- OPTEX-CLIENT: Processor oriented to provide OPTEX services on a client computer that uses a model locally or establishing a connection to a remote server that provides services to solve optimization problems. This role can be assumed by OPTEX-EXE, OPTEX-EXCEL-MMS and OPTEX-WEB. The final user can build his own OPTEX-CLIENT.
- OPTEX-CONTROL-SERVER: Task dedicated to managing the connections from a remote server with multiple clients requesting OPTEX services optimization.
- OPTEX-SERVER: Remote processor aimed at solving mathematical problems associated with an optimization model that has established a connection to apply the solution to a problem. OPTEX-EXE assumes this role.

Transferring files can be performed under any of the following ways: EXCEL books; CSV files or data stored on a SQL server to which access OPTEX-SERVER.

OPTEX CLIENT – SERVER ARCHITECTURE



7. OPTEX DOWNLOADING

If you need more information or you are interested in OPTEX Expert Optimization System, please contact us via rcadt-it@rcadt.com