Acquisition and report of environmental control units

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Dissertação de Mestrado

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To my friends and family,..

Acquisition and report of environmental control units

Abstract

During the last years the world society has been alarmed by the consequences that the modern Human behaviour, regarding the use of energy, production of waste and CO2 emissions bring to our planet environmental problems. It is established that the CO2 emissions from the different sources (industrial sites, energy production, transports) are causing a considerable change in the world climate commonly known as Global Warming. As all the players in the human society, in particular the commercial organizations have been forced to change their behaviour and seek for more efficient technologies to support their production processes and operation activities. In order to track, analyse and report the achievements of the use of more efficient and green technologies several market opportunities has been created.

Our project aims to help the development of a Carbon Accounting Software (CAS) to assist the organizations in all the processes concerning the data acquisition and reporting of environmental figures.

During this research we found several standards for Carbon Reporting (GRI, CARBON DISCLOSURE PROJECT) that establish frameworks to help the organizations in the reporting processes. Using a cross analysis between these standards and a group of sustainability reports from organizations in different sectors (automotive,and chemical) we established some data profiles and reporting behaviour that lead us to the requirements of a CAS concerning it should handle the gathered data and also how to provide the best structure to produce the correct reports, such as :

- Environmental figures basic portfolio
- Suport of the organizational structure
- Suport of the multiple available standards and possibility of define new ones.
- Input/Output methods to simplify the data insertion and data analysis.
- Relation of environmental figures with entities of a organization in different granularity levels.

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A prototype for a CAS has been designed, in particular its data model, aiming to meet all the requirements and defining meaningful methods to present the data that is gathered. Concerning the data acquisition and presentation we established a multi-unit system that allows the user a dynamical change between compatible units. In order to improve the meaning of the graphs created specially when comparing figures in which the ranges of data present a big variation (Co2 Vs M€) we developed an adaptative method to set the axis limits into the graphical presentation.

Acknowledgements

I would like to write some words to remember all the persons that help me in the achievement of the conclusion of this project. I will not nominate them but I will be forever grateful, I would like to address special thanks to all my colleagues in SOLVE-IT which help me in all the situations that I needed,

To Mrs, Gordner and to Prof. João Falcão e Cunha that help me in the developing of the project showing always interest to help in all my questions, their support and knowledge help in the development and analysis of my own ideas making them clear and concise,

Thanks

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Index of Abbreviations

BIRT	Business Intelligence Reporting Tool
CAS	Carbon Accounting Software
CDP	Carbon Disclosure Project
CO2	Carbon Dioxide
EF	Environmental figures (CO2 , VOC , Energy)
ER	Entity Relations
GHG	Green House Gases
GHGP	Green House Gas Protocol
GRI	Global Reporting Initiative
GUI	Graphical User Interface
KPI	Key Performance Indicators
RCP	Rich Client Platform
SQL	Structured Query Language
VOC	Volatile Organic Compounds

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1 Introduction

Focusing in the acquisition and report of environmental units this project will present and analyze different methodologies in this field. The goal is to establish and define a software product, Carbon Accounting Software (CAS), to group all the relevant information in this area.

The project aims to establish a methodology that suits the current standards imposed by legal constraints and also matches the most relevant standards that are currently used in a global scope.

In the technical side the project will approach the database definition of the software and also the methodology to establish and analyze the different figures.

This report is organized in six chapters. The **first chapter** gives an overview of the project framework and how it is integrated in the company strategic guideline. The **second chapter** shows an analysis of some software solutions already established in the market and also shows the most relevant projects in the definition of standards in Carbon Accounting. The **third chapter** points out several particular aspects that are related with the carbon accounting and analyses several particular characteristics of the environmental figures that a CAS should handle. The **fourth chapter** present a solution that intends to fulfil all the requirements presented before and define which kind of solutions should be implemented in the software, presents some methods referring to the data aggregation and presentation, and also the behaviour guideline to the software based in the Deming cycle. The **fifth chapter** presents the developed prototype, with a special emphasis in the database model and in all the data structure and gathering possibilities. The **sixth chapter** summarizes the main conclusions and recommendations for future work.

1.1 MVI – SOLVEIT

SOLVE-IT is a child company of the MVI Group, this company produces and develops IT solutions for different industries. Currently the main costumers come from the Germany Automotive Producers sector. As a strategy guide line SOLVE-IT intends to diversify the market range to other costumer type. The project is a part of this guide line and aims to increase the product portfolio of SOLVE-IT, presenting a solution on the Carbon Accounting Software (CAS) market.

1.2 ECOAssistant

The current project is faced as an opportunity to put together all the know-how that Solve-IT acquire in several years of software development to multinational industries. Currently the carbon accounting Software sector is expected to grow 600% by 2011,[1],

SOLVE-IT intends to create a software solution to fulfil the requirements of this growing market, conscious about the difficulties that this will represent, SOLVE-IT invest in a research project aiming to establish their software requirements and specifications.

Project Methodology

In an early stage of the project it is important to define the market of this kind of product and also establish the basic requirements that a possible costumer will see as important features. Based on this research we are able to design a solid base (technical and conceptual) that allows the product to expand and adapt itself to a real reporting problem.

We consider as critical the Database development since this will be the future base to produce all the reports and present the information in a meaningful way.

The point of this project is not to develop the tool itself, but specially define the requirements that should be taken into consideration. This definition will focus not only in the technical side (Database, GUI, reports) but also in the data portfolio that this product intends to report. This is important in order to implement special functions that fulfil the market requirements.

2 Overview of State of Art in Carbon Accounting Software

The state of the art analysis in this field will consider two types of entities, in one hand we will find several organizations that try to establish a “standard CO2 reporting methodology” across the world, making all the information that the costumer can provide aggregable in a similar way along different companies. In the other hand we find several entities that produce tools to report carbon emissions and other environmental figures, this entities represent the direct concurrence to our product, they should be analysed in order to see what is already available in the market and take it into consideration in the development process.

2.1 Reporting standard projects

- GHGP - Green House Gas Protocol
- GRI - Global Reporting Initiative
- CDP - Carbon Disclosure Project

GHGP - Green House Gas Protocol

Green House Gas Protocol (GHGP) is known commonly as the most widely used international accounting tool for government and business leaders to understand, quantify, and manage greenhouse gas emissions. The relevance from this protocol to our project is relatively small, considering that the information presented on it refers mainly to the calculation process of the Green House Gases emissions in order to obtain an emission value based on a fact or activity. This protocol normally represents a key aspect in software projects from the group of Carbon Calculators. Considering that our project do not focus this aspect this protocol is not relevant in our analysis [2].

GRI - Global Reporting Initiative

Concerning Reporting Methodology, GRI represents a base in any sustainability report. GRI was created in the year 1997 and since then started producing a framework for all the companies that intend to produce a sustainability report [3].

This framework first release was in the year 2000 and since then continuous improvements have been made to it. Currently the GRI framework is the world’s most widely used sustainability reporting framework.

Currently in the third version GRI (G3) Framework consider several different base topics in the sustainability report, regarding the scope of the project this analyse will focus only in the environment topic.

The approach used in the G3 framework is represented in Figure 1, analysing the Figure we can see that two main questions are stated.

How to Report? And What to Report?

Figure 1 – Scheme representing GRI approach

Part1 – How to Report?

In this part the framework state three main sections of the reporting process. The first section covers the reporting principles of materiality, stakeholder inclusiveness, sustainability context, and completeness, along with a brief set of tests or each principle. Application of these principles with the standard disclosures determines the topics and indicators to be reported. This is followed by principles of balance, comparability, accuracy, timeliness, reliability, and clarity, along with tests that can be used to help achieve the appropriate quality of the reported information. This section concludes with guidance for reporting organizations on how to define the range of entities represented by the report (also called the 'Report Boundary'),[3].

Part 2 – What to Report?

Part 2 contains the standard disclosures that should be included in sustainability reports. The guidelines identify information that is relevant and material to most organizations and of interest to most stakeholders for reporting the three types of Standard Disclosures:

• **Strategy and Profile:** Disclosures that set the overall context for understanding organizational performance such as its strategy, profile, and governance.

• **Management Approach:** Disclosures that cover how an organization addresses a given set of topics in order to provide context for understanding performance in a specific area.

• **Performance Indicators:** Indicators that elicit comparable information on the economic, environmental, and social performance of the organization.

Following this methodology and reporting the different indicators represented in this guideline will lead to a DATA profile that allow the comparison between all the organizations that follow this framework.

Boundary Definition

The boundary definition represents which granularity is used to measure the environmental figures. The granularity can vary across an organization considering differences in the reporting technology, although it should be possible to aggregate data with different granularity.

Environmental Sector

Considering that the framework already takes into consideration the major governmental rules related with reporting of emissions, it represents a base to any company in the process of reporting Environmental figures.

The following list present all the core indicators of the framework related with environment.

Table 1 – List of Enviromental core figures (GRI Guidelines) [3]

List of Figures GR3
EN1 Materials used by weight or volume. EN2 Percentage of materials used that are recycled input materials. Aspect: Energy EN3 Direct energy consumption by primary energy source. EN4 Indirect energy consumption by primary source. Aspect: Water EN8 Total water withdrawal by source. Aspect: Biodiversity EN11 Location and size of land owned, leased, managed in, or adjacent to, protected areas and areas of high biodiversity value outside protected areas. EN12 Description of significant impacts of activities, products, and services on biodiversity in protected areas and areas of high biodiversity value outside protected areas.

Aspect: Emissions, Effluents, and Waste
EN16 Total direct and indirect greenhouse gas emissions by weight.
EN17 Other relevant indirect greenhouse gas emissions by weight.
EN19 Emissions of ozone-depleting substances by weight.
EN20 NOx, SOx, and other significant air emissions by type and weight.
EN21 Total water discharge by quality and destination.

Considering all the elements presented in the table 1 it's possible to define a profile concerning the environmental impact of a company. In a sustainability report that follows the GRI guidelines we will find all this core indicators represented in a global view, it do not mean that is possible to establish a comparison between different reports in a simple way. The GRI framework is not clear in the definition of the units that should be used in the reports leading to wide diversity of presentation methods along different organizations. [3]

CDP - Carbon Disclosure Project

Carbon Disclosure Project consist in an organization that created a standard enquiry to address to companies around the world. They start their activity in the year 2000, and after 3 years the enquiry was ready to address to several companies. This questionnaire includes a wide group of questions related with Green House Gases (GHG) emissions. In the graph below it is possible to see the evolution of the number of answers gathered by this project.

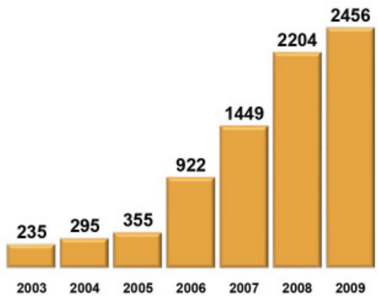


Figure 2 – Number of Responses to CDP Prooject (source: CDP website)[4]

As we can see the evolution is clear and this project is currently a reference around the world in GHG emissions reporting. Currently more than 2500 companies reply to the enquiry of CDP. Based on a response of a company it's possible to define a complete behaviour profile of the company concerning the GHG emissions, it also include some questions concerning witch risks the company face and expect based on the GHG emissions problems,

All the questions are made in a way that they match the GRI indicators enabling some kind of standardization across both projects. Currently the questionnaire that is addressed to the companies is in the seventh version (CDP7), it has been improved since the launch in 2003. After a analysis of the data presented by several companies we conclude that although the project represent a big improvement in the globalization of carbon reporting we still find some inconsistence in the answers from the different companies, It can occur that two companies answer to the same question with a completely different granularity of the data and also clustering it in a not standard way like it´s shown in the table 2. [4]

Table 2 – BMW AG and PSA Group answers to CDP2009 enquiry [5] [6]

CDP 2009	
Answer from PSA – Peugeot - CDP 2009 11.2 Gross Scope 2 emissions in metric tonnes CO2-e by country or region	
Europe	**330947**
Rest of World	**36138**
Answer from BMW AG – CDP 2009 11.2 Gross Scope 2 emissions in metric tonnes CO2-e by country or region	
Germany	**580753**
Austria	**32544**
South Africa	**47280**
USA	**52801**
Thailand	**942**
China	**62934**
India	**1428**
United Kingdom	**96353**

After this short analysis of the three main approaches to define reporting standards we decided to take into consideration the data presented by the GRI framework considering that it is presented in a clear way pointing out the main topics that should be included in a sustainability report. The figures presented by GRI framework represent a common portfolio that should be present in a CAS. The definition of a basic set of figures should be considered as a start point, the costumer should adapt it considering their specific requirements.

2.2 Software Houses

This section will analyse several software houses that develop commercial solutions in the sector of CAS:

- Enablon
- PE International
- ECOIntense

In the selection of the entities for this section we take into consideration several aspects.

We select Enablon because is the company that have the biggest customer portfolio (considering that is exclusively dedicated to sustainability reports) and have been several times awarded as an excellence example in this field, concerning the other two, both represent German entities developing similar solutions for the Carbon Accounting Report, those entities can be seen as the direct competitors from SOLVE-IT in this market and so have a big importance concerning this project. All the information presented in this section must consider the commercial restrictions imposed by these entities, it´s hard to define the real capabilities of their software since they normally don´t supply demo versions. In the case of Enablon even the access to screenshots is restricted. The scheme bellow presents all the main players in the carbon accounting market.

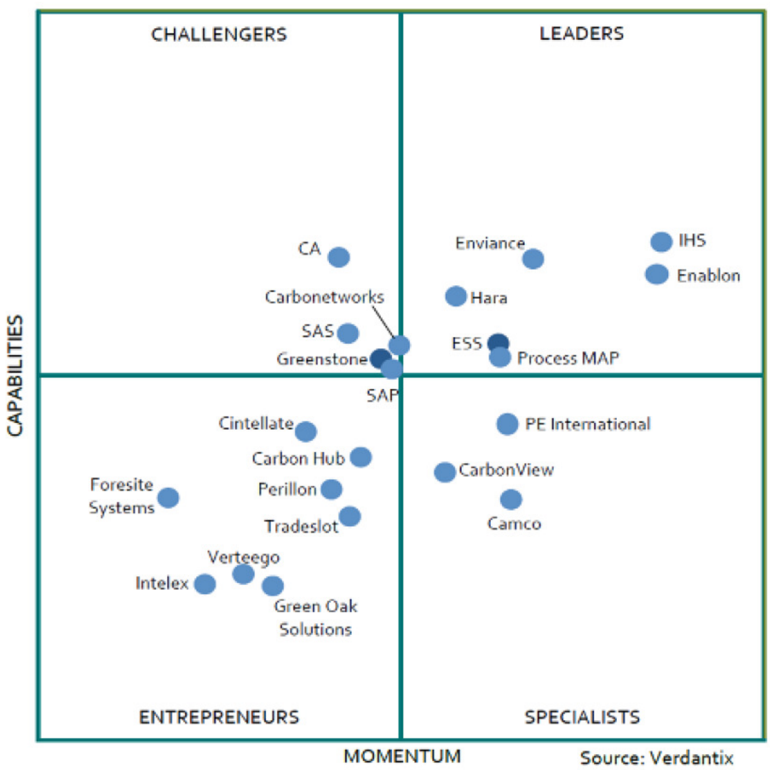


Figure 3 – CAS marketing profile (source : Verdantix) [7]

ENABLON

Enablon is currently one of the leader companies in the developing of Carbon Accounting software; it holds a big and diversified costumer portfolio. The information presented is based on some material supplied by Enablon through their marketing department.

The solution presented by Enablon claims to be the most flexible solution available in the market allowing the user to create their own organizational schema and report based on that. It's also stated that their software suite comply with the protocols mentioned above. [8]

The software solution presented by Enablon follow a web-based concept which allows the reduction of the installation time in multi-site companies. Their solution already integrate several methods in order to automate the measurement of figures through the use of intelligent sensors, this feature should be seen as a major advantage considering that it increase the automation level of the reporting process,

Enablon strategic guideline do not integrate the customization of the software to a specific costumer, even considering the wide range of capabilities of Enablon´s solution this point can be seen as a disadvantage compared with other small players in this market.

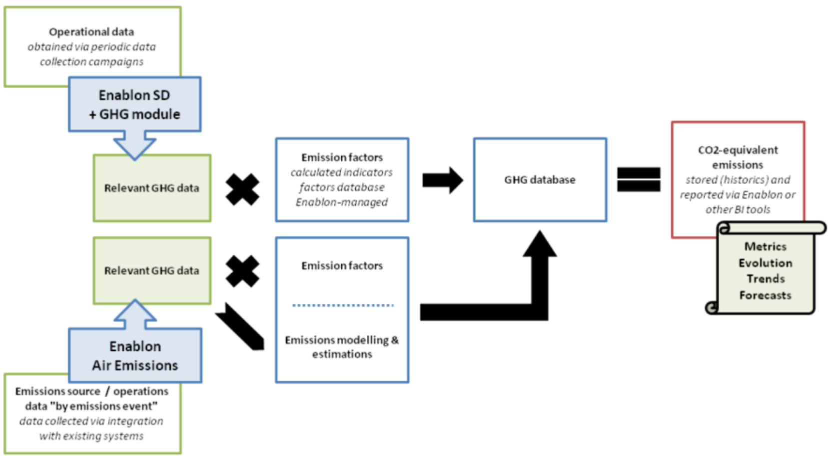


Figure 4 – ENABLON system secheme (Enablon)[8]

In the Figure 4 we can see a schematic representation of the Enablon system.

PE International

PE International is a sustainability consulting company that worked in this field in the last 20 years, their skills are based in a strong know-how and experience. In their product portfolio they present a software solution for carbon accounting named SOfi that allow their costumers to report carbon emissions and measure their goals and offsets targets. This company is an acreditated Provider from CDP and also from GRI [9].

The product range of PE International is divided into two main products: SOFI and GABI. Sofi is a typical CAS that uses a web-base solution to store and report environmental data in an organization. This product presents a wide range of capabilities including forecasts and goals definition based on governmental guidelines. One of the main disadvantages of this solution is the complexity of the customization process that normally should be supported by a PE International consultant. The Gabi software is a life cycle product management tool that establishes a scheme for each process or product in order to define a sustainability profile of each product. This software can help in the development and design process of a green oriented product. One of the main advantages of PE International in this market is the integration of both software solutions in order to relate de environmental reports produced by Sofi with the product overview provided by the Gabi solution. This increases the granularity of the reported data and allows a better tracking of emissions, energy consumptions or waste production.

Ecointense

Ecointense is a software house that also develop a CAS, the product presented by them is called ECOwebdesk. The software is composed by 4 different modules: Organization Administration, Eco-controling, Auditmanagement and legal compliance. In the first module the software manage the organization structure handling the facility management, process and responsibilities.[10] The ECO-controling is responsible for all the data gathering and reporting. The audit module establishes an action plan for the gathered data allowing the user to establish and define goals in order implement corrective plans. The legal compliance module integrates the previous referred emissions standards projects presenting the data under this framework. The modularity of this software can be seen as a advantage specially considering small organizations that do not need to report their data to exterior entities. The system uses a entire web-base interface which reduce all the installation process and maintenance. The storage of the information in the servers from ECOintense can represent a issue for some costumers, the information gathered by a CAS is sensible and should be handled with the same security level as for example financial information. During the development of the project we had the chance to watch a demonstration of the software, it was clear that the system present some difficulties in the adaptation to new data profiles that differ from the ones that are previously settled.

The analysis of several main software producers gives a view of the current market situation and trends. The main point remains in the flexibility vs. standardization of the products, they must be flexible to accommodate the different requirements from different costumers but also must follow the standardization projects to present the results in a meaningful way,

3 Carbon Accounting- Why ? What ? and How?

The World society faces a strong trend to reduce the overall emission in a global way, the first step to achieve this reduction is the trace back of the emissions. This pressure is growing at a high rate increasing the necessity of solutions to manage and report the energy consumptions over complex organizations. This is the only way to prove to the society and to the stakeholders that the investment from an organization is actually producing measurable results in the environmental protection.

Establishing the GHG (Green House Gas) reduction as a target is a simple way to define a global reduction and also increasing of efficiency in the energy use. Considering that a normal company can use several types of energies and within these types we will also find different sources, the amount and diversity of data to compare will lead us to a necessity of standard measure behaviour. During the past years several reporting standards like CDP and GRI were developed to fulfil this requirement. It is recognized that they achieve good results mainly when the goal is to compare similar products and their carbon footprint. The problem will become clear when we try to compare products from different categories or for example compare a service with a product.

The project scope will focus on the definition of structures that support the production of reports that match the necessities of an Organization Management Team. The referred structures include the database model and also the definition of a basic data portfolio that should be included in the package.

3.1 Project Requirements

Considering that we want to be as flexible as possible, the project requirements should not include any reference to a specific technology used in a specific industry or sector; only using this approach we will be able to match a wide range of costumers.

- Accommodate organizational structural changes
- Management of Permissions (Users and Data)
- Aggregation of DATA methods

Accommodate organizational structural changes

Big and international organizations normally don´t have a fixed structure, they change according with acquisitions, spin-offs and structural reorganization, This will lead to a change or update in all the reporting structure. To match this fact the tool must accommodate and deal easily with this structure changes.

The tool must allow a high level of customization concerning the structural changes and even different views from the same reporting units.

Management of Permissions (Users and Data)

The data that is stored in a CAS is normally regulated under strict confidentiality rules concerning the non-disclosure of this data to the outside of the organization. The tool must be able to handle different authorization levels along the organizational structure enabling the possibility of implement different roles for the different users. Considering a multi-site structure a user role should not be unique, the costumer must be able to set it in a dynamic way. A User must access only the data to which he has permissions. In the customization process the costumer should specify all the possible roles of a user and also hierarchy of permissions.

Why report Carbon Emissions?

As stated in the previous chapters the Carbon Accounting represents a new reporting field for the companies that want to play a role in a close future. Considering this new trend the big players in the reporting field try to adapt their solutions to this new demand. The environmental control represent a new tradable asset in the future market, in opposite to the traditional reporting figures the environmental control is completely transversal in all the organization and can be measure in so different ways that can include the energy consumption of a industrial machine and also the paper printed in a office printer. The value of the reports produced regarding this kind of figures is directly related with how accurate they represent what physically happen. Considering all the standards presented before, the system must be able to produce reports that can match a wide range of requirements.

Define the balance between Flexibility Vs Complexity

The balance that this kind of system must achieve between the flexibility and the complexity is a hard point to define. In one hand we have the need of a flexible system and in the other we have the knowledge that with the flexibility increase, the developing and customisation time will rise, nevertheless a non-flexible system will not match all the needs of a complex organization. Below we present two examples of different complexity, they show the need of a flexible system that accommodate the different complexity levels in a similar way in order to permit to establish relations between both examples .

Example 1.1

2 Ton Co2, BMW AG , Plant 1.1, Machine 2, Dingolfing, March, 2009, GRI (EN10)

Example 1.2

200000€ Electricity , BMW CHINA , Year 2009

Whit these two examples we intend to show how different can be the data that is stored in a CAS . The first example represent a high granularity level where is possible to track which machine is responsible for a specific emission . In the second example is presented a overall value for the energy consumption over a one year period . Considering for example that we intend to present the overall carbon emissions of BMW Group for the year 2009 , both values must be aggregated in the final report. This aggregation must be possible considering the relations established in the system , Is possible to define BMW CHINA and BMW AG as part of BMW GROUP, the value gathered for March 2009 is part of the overall value of year 2009 . The ammout of money spend in electricity can be transformed in CO2 equivalent. Using this approach is possible to relate both examples in order to count them together in a final report.

Considering both examples after a simple analyse we can raise several questions that can be included to identify each value.

What?

What are we measuring, what Unit is represented and from which group it belongs.

Where?

Where are we measuring it, in which city, in which plant and in which machine?

When?

Time period to what the value is referred.

From this example we can define a minimum complexity level that includes at least the following references: What, Where, When. Using this approach is possible to define all the data gathered in the system in order to allow a multi-level aggregation even when different granularity is used in the data input.

As any common report the boundary definition represent a key aspect in the definition of a report. In this boundary we must include restrictions that reference a specific value, keeping it always defined and preventing that the system add or mix values that do not refer exactly to the same place in the same time. This boundary definition must represent the real restrictions imposed either by legal factors or by physical restrictions. All this definitions must be stored in the system in a customizable way taking advantage of the database structure. This will lead us to a necessity of define in the system the physical structure of the organization, the figures that we want to measure and the timelines associated with it. Considering that the system is not self-adjustable the reports can only be based in previously defined dimensions.

Aggregation of DATA

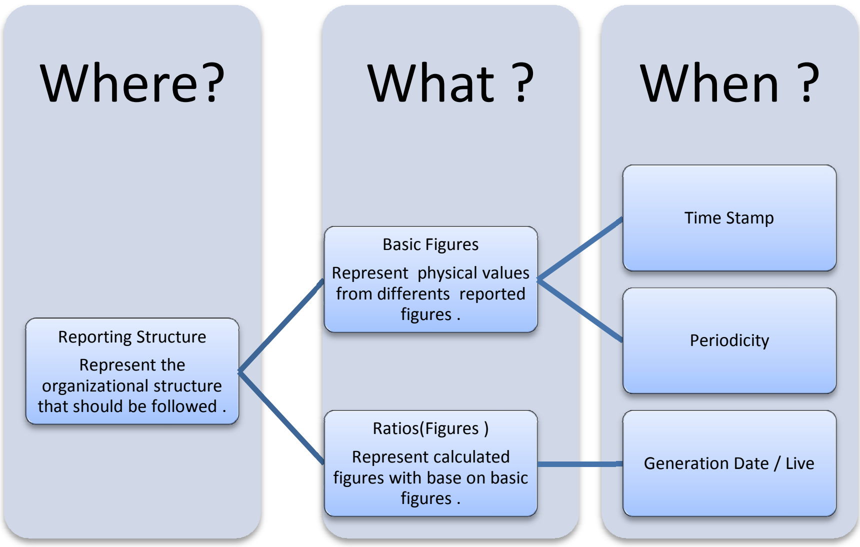
The system must allow the user to aggregate the data according with the organization structure or with any other request that could be necessary. The granularity of the data should not represent a issue when it is being gathered, it should be possible to put together data that represent the same figure even if it follow a different periodicity, for example represent a figure that is measured in a year base along with one that is measured in a monthly base, converting in this case the months to years. The granularity is a questions that should be handled by the system, it should be possible to create a combined figure that is based in two basic figures with different periodicities.

What to report And how to build a report ?

After an analysis of several sustainability reports (Bayer [11], BMW AG[12], we get some key figures about the general requirements in a CAS.

As you change from sector to sector along the company's portfolio you can clearly see that the figures presented in this reports vary according with the sector, even when all of them state that they follow the GRI guidelines. This represents a big issue in the developing process of the accounting System.

The following scheme (Figure 5) present a structure that the data stored in the system must follow, this can be considered as a basic rule set for any report produced by the system and also as a key to all the data insertions. If we consider this rule we can integrate and answer to all the questions that can be seen as meaningful in a report.



In the following section we present a portfolio of figures than can be used to resume all the data that is critical in this kind of analyse.

Figures Portfolio

After the analysis of the reports presented in the previous section we decide to create a figure portfolio that can be used as framework in a general case.

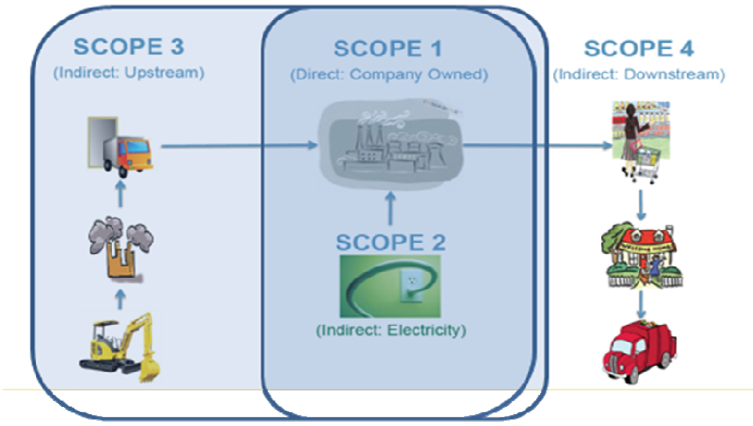
In an industrial environment all the figures are relevant and in the most part of the cases can be related between themselves. The point of this study is to define a portfolio that allow the costumer to have a knowledge base that allow a simple, quick and also meaningful analyse of the actual, past and future situation along the organization.

The figures can be clustered in different types: with physical meaning, financial background, and production related ones.

Physical Units

The Physical units represent figures that are related directly into the process´s, even considering that the goal is to have a general solution and across the industry we can find a wide diversity of processes, it is possible to identify a trend that is present in all the reports.

Co2 – Co2 is present in all the reports, normally to simplify the presentation of the data all GHG are converted to CO2 using a conversion factor[1] this represent a relation between the common GHG and the CO2 . Normally the CO2 value is splitted in different categories according with its origin (Direct, Indirect).



Volatile Organic compounds - In all the reports that belong to industrial companies this value is presented as indicator of the technology level used along the process. A reduction of this figure represent that the company is improving their industrial process and changing to a clean technology.

1 1 Some GHG gases have a greater impact on climate change than others. Therefore, different greenhouse gases will have different levels of CO2 equivalents (the amount of CO2 which would have to be released in order to have an equal impact on the atmosphere). Examples 1 kg of CH4 = 23kg CO2 Equivalent . The same approach can be used in energy conversions : 1 Kwh Produced using Natural Gas = 0,123 kg CO2 equivalent.

Waste - The Waste is present in all the sustainability reports, it represents the efficiency of an industry in the use of raw materials and also the efficiency of their internal recycling processes.

Energy - Energy indicators appear normally related with CO2 emissions, although it can be represented and converted to CO2 equivalent values. normally is important to present it as Energy (MWh) allowing the user to understand the energy consumption profile of the company and also the origin of the energy used (Renewable, Nuclear, Fossil). This will differentiate the CO2 emissions generated by energy consumption from emissions that are generated in industrial processes, increasing the information level that is presented by the system.

Water – The water appear in a sustainability report in a similar way as the Solvent, it indicates the Clean Technology Level used along the industrial Processes.

Production Costs and Investment

Production costs are normally not the key factor in a sustainability report, although they are the only way to establish a bridge and a relation between the Environmental figures and their real meaning compared with other companies from different sectors. When you analyse a company that has a very low emission level you are only able to draw a profile when you relate these low values with the costs related with their production sites. The investment is normally referred in order to allow a comparison between it and the reduction of the environmental figures.

Production Figures

The production figures appearance in the sustainability report are normally embedded in ratios using the Physical Units presented before. They represent the units (parts) produced by a specific company allowing an easy analysis of the direct environmental impact of a product (unit). The figures can be represented in several different ways, normally they are related with the product produced by the company. In the services sector this kind of factors don´t have a strong meaning because normally they are merged together with the production costs

As we could conclude the Physical Units represent the core cluster, but when they are not matched with production values they don´t have any measurable meaning. Normally the second and third clusters are not integrated in a CAS they are imported from the existing systems used by the companies to produce their normal Activity Reports, The clusters definition presented before should represent a base set of clusters, as seen in all the standards presented, this cluster schema can suffer several adaptations that should be made in order to match the sector specific requirements.

Mask to meet General Requirements

Considering all the standards presented in chapter 2, it's a key factor to match the reported values with the indicators presented in the standards. Even when they don´t match exactly the indicators presented in the standard documentation, they should be aggregated or rearranged in order to meet the standardization process. Considering as a basis the GRI framework the system should allow the user to create and generate different views from the same data in order to meet this framework requirements or any other special data structure request.

Time Line

The timeline presented in the reporting process should be as wide as possible. Currently the most used base is the yearly reporting. It's important to keep in mind that as more specific you are in the reported units as more precision you get from your values, allowing a easy relation of increases or decreases in the measured figures with actions and occurrences, Currently all the reports analysed present a maximum of 5 years scope, this time period should increase along the years.

As stated along this chapter the system must include a wide group of features to manage and store the gathered data. The environmental figures portfolio gives an overview of the diverse types and figures that can be found in CAS, this diversity point us to the definition of a flexible and adaptable system to manage and report those figures. In conclusion our system must handle all the topics presented below :

Organizational structure

Users Management (Roles, Permissions)

Data Aggregation

Figures Portfolio (GRI Based)

4 Reporting methods definition

The present chapter intends to present a solution to the problem stated in the previous chapters, This solution will put together several different topics in order to achieve a reliable and affordable solution.

This chapter will be divided into 3 sections, the first refers to the Data Portfolio that must be integrated in a carbon accounting software according with all the methodologies presented in Chapter 2, the second will refer to the technical approach used in the development of the solution and his integration in the organizations that it intend to serve, in the third and last section of this chapter a prototype will be presented, intending to achieve the basic requirements presented in chapter 3

Data Portfolio

The data portfolio is a representative set of data that should be included in the project. We define in the previous chapter under the topic Basic Units a set of data that is considered critical in this kind of project according with the analysis from several Sustainability Reports.

This data portfolio will follow the GRI framework, As it is a well established framework, any different approach will lead our project to a non-sense data profile according with the external parameters. The figures presented in the table 2 should represent a basic set of categories.

Technical Approach

The system will be implemented in JAVA since SOLVE-IT has got a lot of know how there and the resulting system will be highly portable and independent of the operation system in use. By using Eclipse as development basis a user-friendly graphical user interface can be realised. The system should be developed using a Eclipse-RCP allowing a simple and easy migration to a full web-based version.

Waterfall Vs Agile software development

There are two typical approaches in the software development, Waterfall Model and AGILE Development. Inside these two models we can find several different versions and adaptations. In this section we will present a short review of both models in order to choose the most appropriate for our project.

The Waterfall Model Represented in the Figure 7 below is a classical view of the software development. It establishes several linear and sequential steps that normally follow the presented order, The Waterfall model establish that one step only take place after the complete definition of the previous one. This model present several advantages in the handling of big projects, the requirements and definitions are well supported by documentation. This require that the developers can have a clearly view of the future problems and questions in order to consider it in the early steps, This model have some restrictions in the re-adaptation of the software during the last steps, considering that all the requirements and design is already established when the coding process start any question that surge during this step will originate a mandatory rollback of all the previous steps, [13]

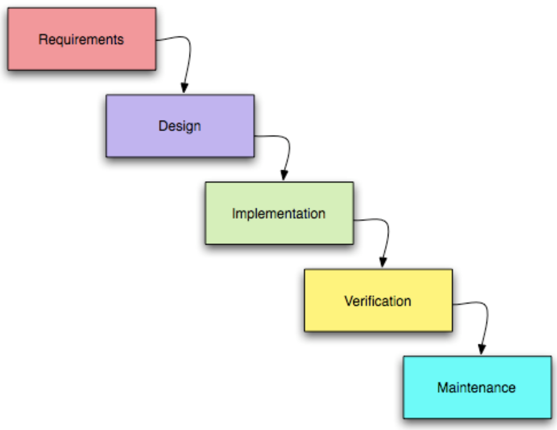


Figure 7 – Waterfall Model [13]

The Agile development becomes a reality during the last years. It has several standards and methodologies (AUP, XP, OUP)2 [14] that present small differences and trends. The Agile Methodology gives emphasis to working software instead of documentations as soon that a requirement is established the coding process starts immediately. Agile development methodology attempts to provide many opportunities to assess the direction of a project throughout the development lifecycle. This is achieved through regular cadences of work, known as sprints or iterations, at the end of which teams must present a shippable increment of work. This kind of approach also takes the costumer inside of the development phase allowing the developers to get a fast feedback over the implemented features. Unlikely the Waterfall model the Agile approach is suitable for medium-small projects where the communication along the team is easy and consistent. The implementation of changes can occur at any time without major problems. The packaging of the software in small parts allows that some modules are used in other projects just suffering small adaptation (Example: Login Plug in),

Based on the presented reasons the Agile Method suites better the requirements for this project.It will allow a shorter time period till the first functional release and that can be used to start the sales process and also will allow a higher capacity of adaptation to new requirements from the costumer side and also from the market itself, which represent a major advantage in a sector that is constantly suffering changes.

The product will be spitted in three main clusters:, CLIENT, SERVER and DATABASE, The CLIENT will handle all actions of the users and also the presentation

[2] Xp – eXtreme Programing, AUP – Agile Unified Process, OUP – Open Unified Process

of the data provided by the SERVER, In the SERVER cluster is stored all the business logic of the software itself, it handles the communication with the CLIENTE and establish the required transaction with the DATABASE. The Scheme below present the structure refered.

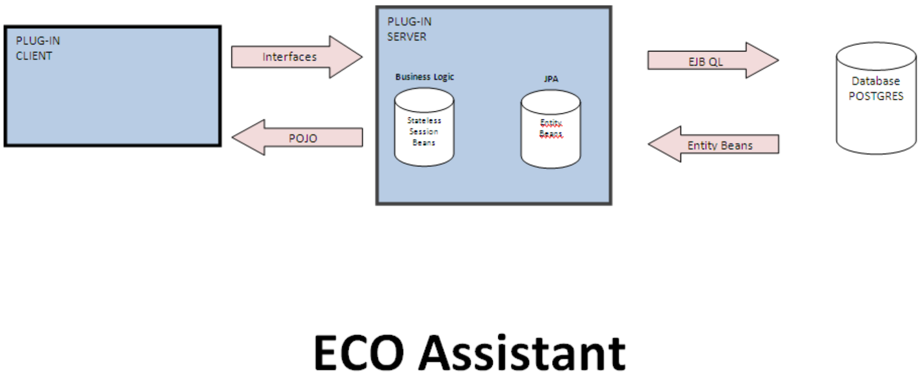


Figure 8 – ECOAssistant structure

This kind of structure will allow a consistent Agile development, each cluster can be developed in different teams and the required changes or adaptation will never affect all of them, they will mainly take place in SERVER cluster,

4.1 The Deming Cycle

As a internal project the requirements must be established first in a empirical way and after trimed according with the customer feedback, this trim to the requirements is out of the scope of our project, A common approach to the environmental control is the use of the Deming Cycle [15], presented bellow in Figure 9,

Figure 9 – Deming Cycle [15]

This establish a key set of processes and capabilities that must be embed in the software development. Each step of the Demming cycle can be translated into a set of feature in the final product.

Plan

The Plan step is related with the establishment of several goals or targets to be achieved in a defined timeline. Allways addressing to the figures establish in the data portfolio, the software must be able to ménage a set of plans or measures to be taken in a specific group of data or location in the organization.

This will keep the Planed actions in a structured and logical way. They can be related with figures, users or locations,

Do

The DO step will introduce the relation between the planned actions and a new set of measurable targets in the figures where it should be used,

Example :

Action 1

A planed action is implemented with the aim to reduce the GHG emissions by 10% in a 3 months timeline in Werk 1.1

Planed Action Definition :

Action Target : Reducttion 10%

Related Figures : GHG (Co2, Co, H2O)

Related Locations : Werk 1.1

Related Users : Involved Users Werk 1.1

Timeline : 3 Months

This kind of action will trigger a new set of targets to the figures associated with the Action 1. This targets will be presented to the users that are enrolled with the measurement of this figures allowing them to see the strategic approach related with the planed action in a simple and dedicated form. This will allow the user directly related with the data insertion to introduce a comment in case of any deviation from the established target.

Check

The check step will be related with a higher level in the organization hierarchy, where the user that is responsible to approve and check the measured values will be immediately alerted if any measured unit is out of the expected target, This will allow a constant control of the targets and a easy way to introduce corrective measures when something go out of the expected values.

ACT

The ACT step is out of the scope of the software, it will refer to any action that is trigered in order to correct or reduce a value that is out of the target.

4.2 Report Quality

The final task of a CAS is to present the collected data in a readable and understandable way

There are several types of data visualization methods, from simple tables to complex graphical representation of the data, The question is how much values we can present to the user without losing the meaning of the data: According to Friedman (2008) the "main goal of data visualization is to communicate information clearly and effectively through graphical means.", The process of creating a high quality report follows a basic rule represented by following schema,

Figure 10 – Report Generation Steps

The first step represents the conversion of the real world sample to a data format that can be managed readed and maintained in a structured system (database), this step could be handled in a automatic form thought the use of sensors and measuring devices or introduced in the system by a user, The Data Analyse is strictly dependent from the first step, errors or a bad organization of the data will lead to impossible or much harder task in the analysis. The data analyse cluster together all the processes that manage the data in order to convert it from STATE1 to STATE2 and vice versa, For example if we consider the CO_2 emissions of 2009 we can represent it in 3 or more different ways according with our timeline but in fact they represent exactly the same data,

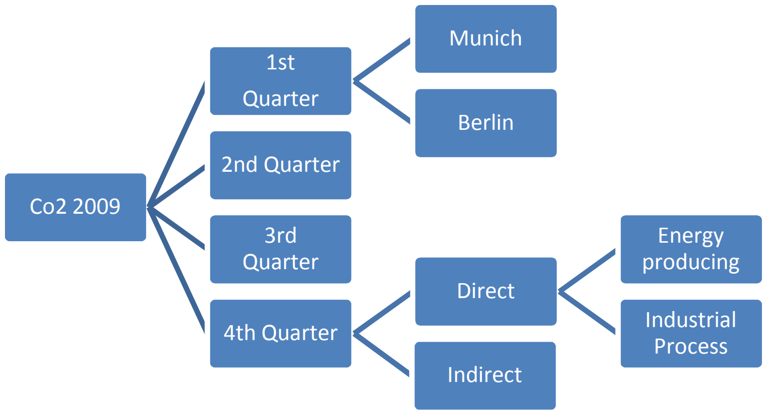


Figure 11 – Multi-level data schem

Although the data presented is exactly the same, the detail level change, this is only possible considering a structured storage method and also several processes of data analysis. The example used above can be applied not only to a timeline level but also for example to different locations and also in the aggregation of different environmental figures.

After the data analysis the goal is to present it to the user. This process is crucial because even when all the steps before are successful accomplished they will not represent a advantage to the final user,

The data visualization can be divided in two main categories data presentation and data type, The data presentation consist in the selection of the appropriated methods to present the gathered data, currently there are a unlimited number of ways to present the data from simple table to complex 3D graphs, Not all of them are suitable for all the types of data for example if the target is to present the C02 measured by a sensor using a sample rate of 1 per second it's clear that a table will not allow the user to understand the presented data considering the amount of values presented using a numerical format, the use of graph will allow the user to see and identify immediately some trends or peaks. The key point is to establish for this kind of data (Environmental figures) which are the more readable ways to present data to the user, considering the output when the user analyse the data and also how the user introduce it into the system, The data type refers to the format of the data that is stored in the system, as a flexible system it should handle different types of data allowing the user to establish relations between them,

4.3 Multi-Unit System

The establishment of a multi-unit system is one of the features that should be implemented in order to allow the adaptation of the data to the different standards. In order to establish this procedure we must break-down the concept of unit in order to redefine it according with our system. Normally the units are defined by a system for example SI, and therefore all the values should be represented using the unit that is referred in the system definition. For example when using SI, all the weights should be represented using the kg (kilogram) and all the lengths should be represented using the m (meter). After the analysis of the GRI reports mentioned previously we conclude that this rule is not always followed by the organizations. Normally in order to present the results in a meaningful way these units are changed to more acceptable units. In some cases this units only suffer the transformation that is already established in the system that is based on multiple conversion of a unit.

This kind of transformation does not represent a big effort in order to understand the presented data considering that the unit stills the same and is only aggregated a multiplier. If we consider a transformation from the SI to the Imperial System the difficulties to understand the data will increase. All the examples mentioned before consider that the company use one of the basic units from an already established system which is not always true regarding the environmental reports.

Several times we find combinations from these systems with unusual denominators for example in the automotive sector the (kg per vehicle) is a common unit to represent CO2 emissions or waste production. These ratios are very useful in order to define the direct impact of environmental investments in the final product.

In order to organize the data in a way that the user can transform it from system to system and also create new ratios based on the available information, our project suggest a relation scheme between all the units. A basic scheme should be included in the system, always considering that the user is able to update or create new units or ratios to fulfil the demand of a report.

In the scheme bellow we find a representation of the system behaviour regarding the comparison between the SI and the Imperial system, nevertheless this kind of relations can be introduce to any kind of variables allowing the system to present all the possible choices regarding units representation,

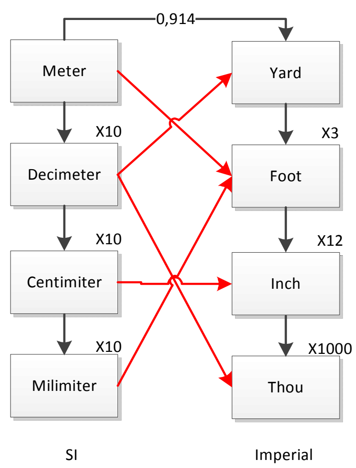


Figure 12 – SI vs Imperial System multi-unit approach

The multiplier 0,9144 is supplied to the system and the red arrows represent some of the relations that the system can create in order produce multi-unit conversions of the stored data.

Condidering a more complex example that envolve a non-standard unit : Kg of CO2 Equivalent. All the GHG can be converted to a CO2 equivalent value by the use of a conversion factor as stated before in this document. Considering that kg of CO2 equivalent is a combination of two basic units : Weight (kg) and a User defined (CO2 equivalent) the system is able to handle the data variable combination of formats, Group of units weight : Kg, g, ton,

Group of user defined GHG : CO2 equivalent, SO, NO,

The user that is responsible for the data insertion can select as unit for example g of SO, and the system store it as previously defined in kg of CO2 equivalent. This can represent a advantage for example when a specific process produce SO and instead of proceed to transformation before the insertion that can lead to several mistakes, the user insert that data as he see it. In the other side the user responsible for creating the report is able to present all the GHG using the unit ton of CO2 equivalent because the system is able to identify and check the existence of this relation,

4.4 Data Visualization

After a deep analysis of the sustainability reports provided by BMW AG [11] and Bayer AG[12] representing companies from different sectors, we conclude that normally the most common representation of data is shaped into a graphical form or through the use of tables. Normally these graphs are simple and present only one figure or a generated ratio for examples (kgCO2 per Vehicle). Below we can see some examples extracted from this reports.

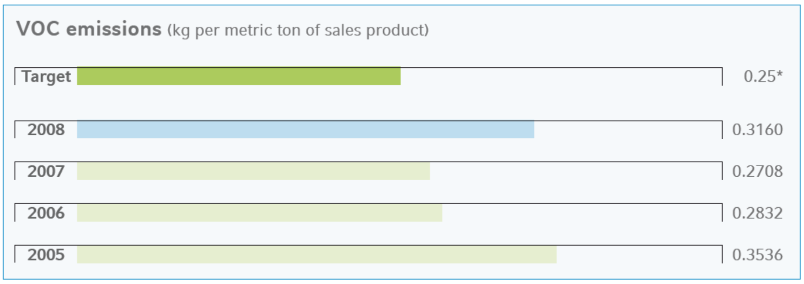


Figure 13 – VOC emissions Bayer (Bayer Sustainability Report 2009)[11]

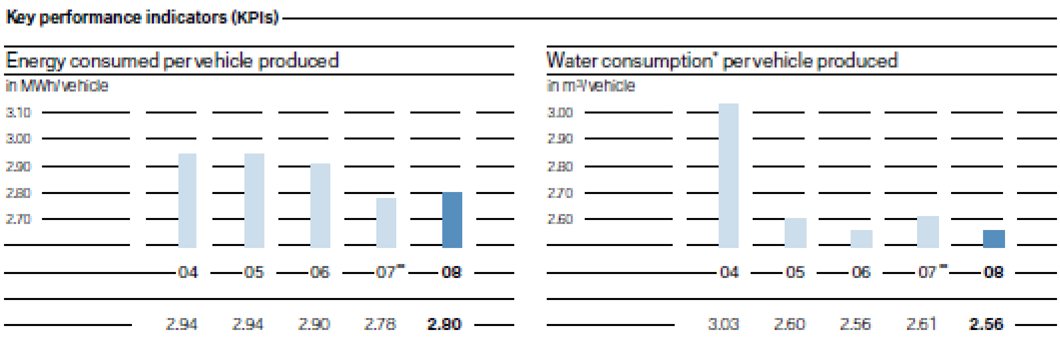


Figure 14 – Enviromental KPI (BMW AG sustainability report 2009)[12]

In both graphs we can see the use of specific units in order to represent a ratio of a figure related with a production unit. The complexity level of this graphs are relatively low in order to allow the user a rapid understanding of what they intend to show. Our software intend to allow the user the creation of more complex graphics keeping easily the understanding of the data. One of the main restrictions in graph bars or scatter XY graphs are the limited number of dimensions that they allow the user to present.

Figure 15 – Axis representation

In the scheme above we can see a simple representation of the axis of bars graph or a scater graph. In the graphs extracted from BMW AG report we can see that the y axis is normally associated to a figure or ratio and the x axis represents a timeline. Adding the use of the axis y2, which allow the integration of another figure to the same graph will present a axis range issue, this range should be adapted and settled in order to present the data in a clear way, For example when we compare CO2 per vehicle with CO2 by plant, the values of the samples present a high variability in terms of range. So we can set each axis to each figure in order to present meaningful data. This adaptation can be done in two ways. We can use the multi-unit in order to search the system and find two units in what the data ranges are similar, or define one figure as primary and define the y2 axis based on the values range of the secondary figures. The user should be always able to define it in a new way, this is just a suggestion from the system.

How to define a axis ?

An axis can be defined using 3 values, minimum value, maximum value and scale.

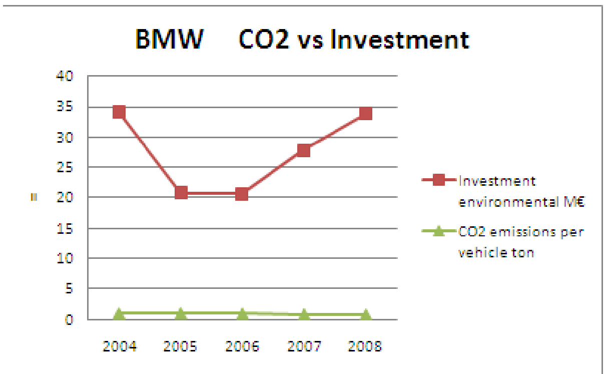
The system should take into consideration the data sample provided by the database in order to precede the analysis and calculate the axis ranges.

The example below show example based on the data extraction of a BMW report.

Table 3 – BMW sustainability data extraction (BMW Sustainability Report 2009) [12]

	2004	2005	2006	2007	2008	Unit
VOC(Volatile Organic Compounds) per Vehicle	2,26	2,07	2,04	2,36	1,96	kg/vehicle
Investment environmental	34200000	20800000	20700000	27800000	33800000	€
Total CO2 Emissions	1169786	1304971	1206391	1298863	1183641	t Co2
Water per Vehicle	3,03	2,6	2,56	2,61	2,56	m3/vehicle
Water	3789703	3417341	3500197	4017541	3682420	m3
Waste per vehicle	318	346	344	376	361	kg/vehicle
Waste	397151	454821	469691	580010	519353	t
Total Energy	3672212	3861253	3959908	4283922	4034442	MWh
Energy per Vehicle	2,94	2,94	2,9	2,78	2,8	MWh/vehicle
CO2 emissions per vehicle	0,94	0,99	0,94	0,84	0,82	t/vehicle

The target is to design a graph that shows the investment in environmental projects and also the CO_2 emissions per vehicle to show that the investment result in a reduction of the CO_2 emissions per vehicle produced. The first graph show both figures represented in a graph using a single axis.



– Graph CO2 vs Investment (Axis A)

In the graph from Figure 16 is clear that the data presentation is not correct because the CO_2 emissions line is almost flat due to the difference between ranges of the figures to analyse. In the graph from the Figure 17 presented bellow is added a secondary axis in order present both figures in parallel, this representation allow the user to define a cause-effect possibility based in the trends presented by the graph lines.

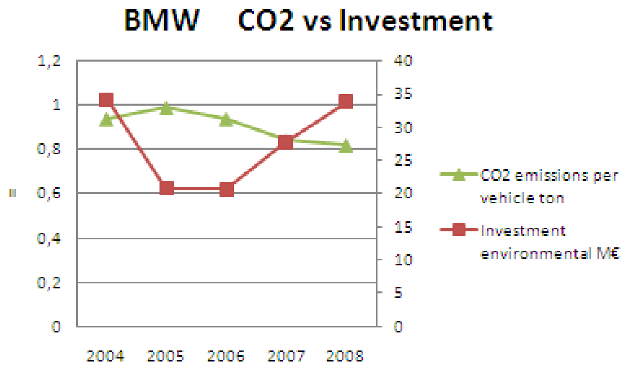


Figure 17 – Graph CO2 vs Investment (Axis B)

This example is valid to a maximum of two divergent figures, in the case of a third figure with a higher value for example Water per Vehicle represented in litters, both figures will present a flat shape due to the differences in the ranges.

Using the multi-unit system presented before the system can search for compatible units that minimize difference between the ranges of the different figures. This will allow the easy construction of meaningful reports in a way that they not only, show a simple figure, but also prove relations between actions and improvements.

Considering the example from the table 3 let´s suppose that we would like to produce a report representing the investment in environmental protection and all the ratio per vehicle of water, energy, CO2 and waste,

Units Analyse

Investment - €

Water per Vehicle – m3/vehicle

Waste per vehicle – Kg/vehicle

CO2 per vehicle – t/vehicle

Energy per vehicle – MWh/vehicle

A possible categorization of the units that should be previously stored in the system can be :

Volume – m3, liter, dl, cl, ml

Weight – kg, t, g

Energy – KWh, MWh, Wh

Financial - €, M€(million €), k€(thousand €)

Units – Vehicle, kVehicle (thousand vehicle)

Considering the available data the user should define if there is any unit that should be maintained in order to fulfil his necessities, this unit will not be changed by the system. In this specific case we select as a fix unit the denominator vehicle, like that the system will not perform any adaptation concerning this unit.

The user should define as well with how many axis the system can work, one or two. More than two axis can be used in specific cases for example to produce radar charts.

The first step of the process consists in define the average of each unit for the specified timeline. The average is the best option to define a value in which the iteration is going to be based, the system must check the case of a big deference between the average and the extreme values of the entire range, excluding in this case this figure from the analysis. These limits should be defined by the user during the customization process of the software. The scheme below in the Figure presents the workflow of the optimization process. When a figure is excluded the system must define a axis in the graph to represent this figure proceeding with the process for the next ones.

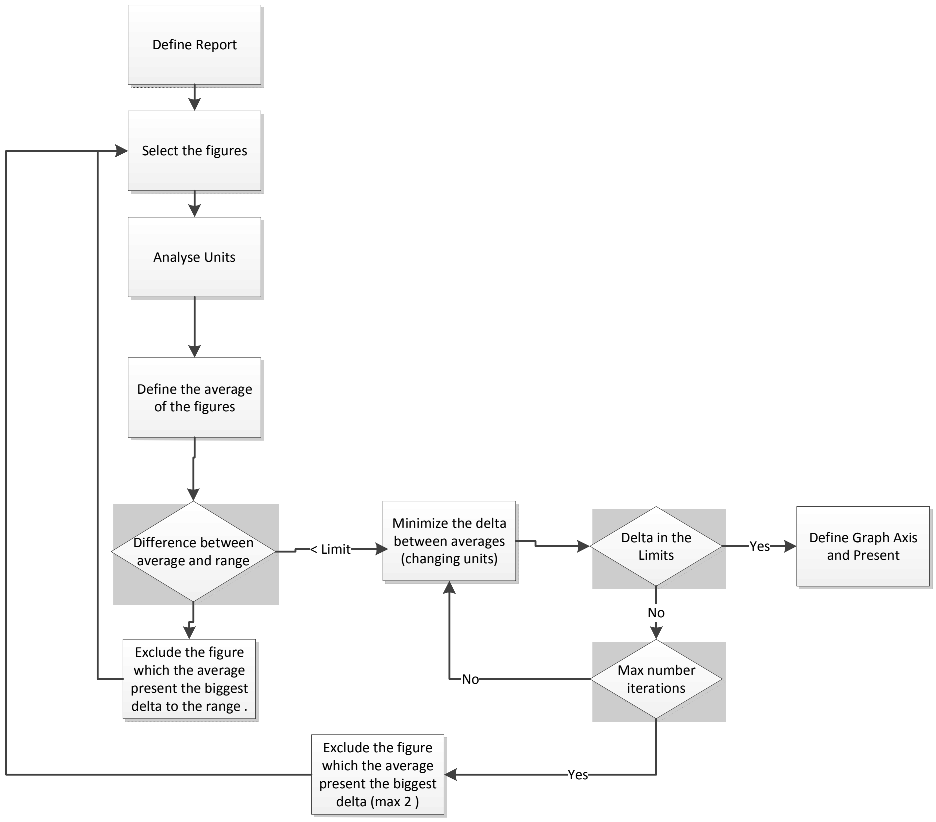


Figure 18 – Optimization process work-flow

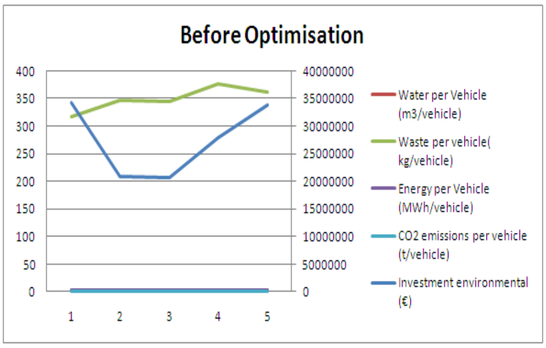
This system intends to help the user in the selection of the appropriate units to use in a report, after it the user can introduce changes or don´t accept the new units scheme presented by the system selecting new ones. The units that are presented in the system should be ranked in order of importance (kilogram rank 1, hectogram rank 5) in order to establish a priority in the minimization process.

For the example presented the system should exclude from the calculation the figure investment and define a axis for it, considering the following averages.

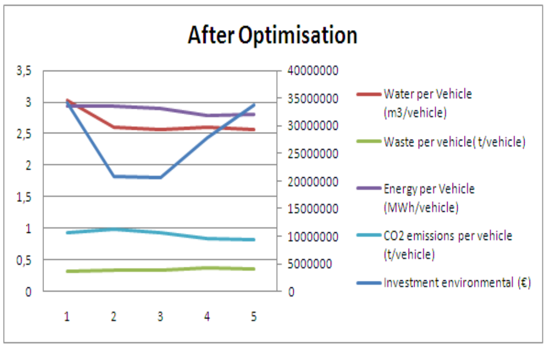
Table 4 – Optimisations of UNITS

	Unit	Average	New Unit	Average
Investment environmental	€	27460000	€	27460000
Water per Vehicle	m3/vehicle	2,672	m3/vehicle	2,672
Waste per vehicle	kg/vehicle	349	t/vehicle	0,349
Energy per Vehicle	MWh/vehicle	2,872	MWh/vehicle	2,872
CO2 emissions per vehicle	t/vehicle	0,906	t/vehicle	0,906

The change of the waste unit from kg to t will promote a better visualization of the figures in a single graph (graphs presented below).



ptimisation



ter optimisation

In Figure 19 it is clear that only the waste and investment figures are meaningful because of the range of the graph, after the unit change of the figure waste and considering the usage of two axis the user is able to clearly see all the figures represented in the same graph.

4.5 BIRT – Business Intelligence Reporting Tool – Reporting Framework

Considering the technology that was selected for the development of the project (Eclipse with JAVA) the usage of BIRT is the best option in the data presentation methods. BIRT is an open source reporting project designed for Eclipse, it presents a group of reporting methods that can be integrated in the application.

The available report types in BIRT are :

- Lists
- Charts
- Crosstabs
- Letters and Documents

These four types of reporting methods present a wide choice for the user, they can be used in a single type or in a combination.

The anatomy of a BIRT report can be splited into four main categories.

Data - Databases, web services, Java objects all can supply data to a BIRT report. BIRT provides JDBC, XML, Web Services, and Flat File support, as well as support for using code to get at other sources of data. Further, a single report can include data from any number of data sources. BIRT also supplies a feature that allows disparate data sources to be combined using inner and outer joins.

Data Transforms - Reports present data sorted, summarized, filtered and grouped to fit the user's needs. While databases can do some of this work, BIRT must do it for "simple" data sources such as flat files or Java objects. BIRT allows sophisticated operations such as grouping on sums, percentages of overall totals and more.

Business Logic - Real-world data is seldom structured exactly as we need in a report.

Presentation - Once the data is ready, we have a wide range of options for presenting it to the user. Tables, charts, text and more. A single data set can appear in multiple ways, and a single report can present data from multiple data sets.

Using a structured database and all BIRT capabilities is possible to achieve all the data aggregation and flexibility required in a CAS. The fact that BIRT is a open source project presents a major advantage since if the developer has the necessity of for example implement a new type of graph, it can be made without major changes in the code, since we can keep the BIRT framework.

4.6 Overview

This chapter present a possible solution to the reporting problem, the methods presented can be applied in order to improve the system flexibility and also the production of several types of reports in order to present a wide range of data. This will match all the requirements in the acquisition of environmental figures.

The possibility of achieve good results in the development of a CAS , is strictly related with the diversity of information gathered. It is not possible to define a usefull system without consider all the points stated along this chapter. Factors as the current standards and typical measuring units should be considered important nevertheless it is necessary a general approach that leave space and possibilities to adapt the system to new requirements considering this aspects. Any approach that does not consider all the key aspects involved in the reporting process will not lead to a good result. The Deming Cycle should be used as roadmap in the software development including features that match and handle in the best way the three initial steps.

5 Carbon Reporting – Prototyping

This chapter focus on the the development of prototype software of a carbon accounting software, all the conclusions gathered along the previous chapters will be taken into consideration in the developing of the prototype. This prototype definition will allow a better understanding of all the problematic presented before.

This chapter will be divided in 3 sections. In the first we will define the database model based on the set of requirements established before, although the scope of the project is not the technical side of the prototype, the database model is critical in the behaviour and capabilities of the software itself. In the second section we will present all the implemented features that must be fitted into the final solution. The last section is dedicated to the output of the product, the reports, how they should be presented and how they should be created in order to meet the normal necessities of an organization that want to report and track their environmental figures.

5.1 Database Model and Requirements

As the first step to design a successful and reliable database model, we must track and establish all the data requirements and also the process and transactions that should be covered by the system. The method used in this definition is Entity Relations Model; this will allow us to develop the database in a structured way always keeping in mind the requirements that are established. During the research process we consider

Entity definition

PLACE

The first entity that we are going to define is related with the Local to who the measure refers to. We are going to call it PLACE, this entity intend to represent a physical place in the organization. It is relevant in this entity to state that they must follow a tree-behaviour between them in order to represent the organizational structure of the company.

USER

The USER entity define any user of the system

ROLE

This entity define all the possible actions that should be taken by one or more users, this will allow the software to have a flexible and manageable permissions system.

FIGURE

The entity figure defines anything that should be measured. Eg. Co2

REPORT

The entity report will aggregate different kinds of information representing the basic output of the system.

Entity Relations Diagrams

In order to promote a better understanding of the system we opt to design the Entity Relations Diagram, in a simple and clear way not including all the entities in the same diagram. Several diagrams will be presented to explain the main relations that we should consider in the database design process.

PLACE – FIGURE

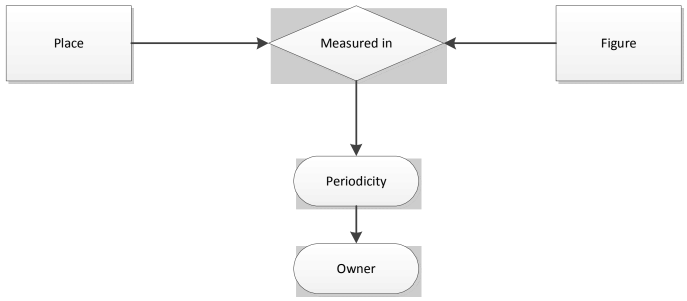


Figure 21 – ER PLACE – FIGURE

The relation between PLACE and FIGURE associate a figure to a physic place, a figure can be measured or tracked in several Places, allowing a global report based on one of the figures.

PLACE-FIGURE-USER

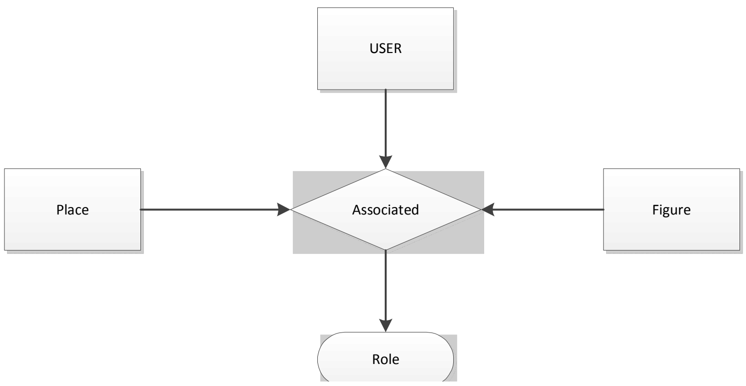


Figure 22 – ER PLACE-FIGURE- USER

This relation defines the task of each user concerning this specific measuring point defining a specific role that is associated to each task. A user can assume multiple roles in multiple measuring points.

PLACE – USER

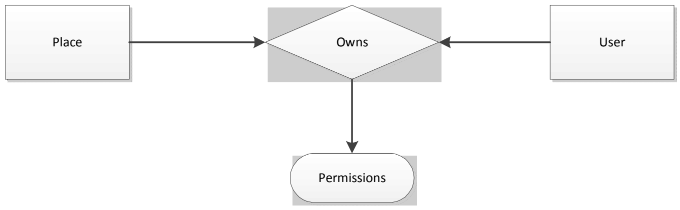


Figure 23 – ER PLACE-USER

The relation between the user and place define the user that is the owner or manager of a specific place. This relation will be affected by a cascade effect according with the tree structure definition. The ownership of a place cannot be considered a role, because it is not associated with any specific figure. This will allow the user to define and associate roles and users to a special figure in a place managed by him,

REPORT – PLACE

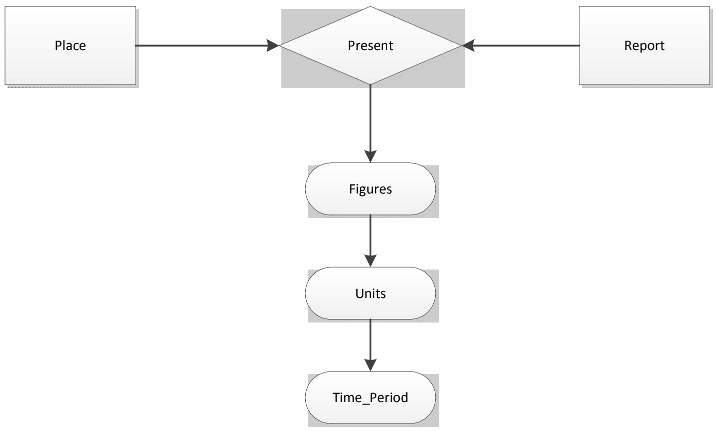


Figure 24 – ER REPORT- PLACE

This relation was created in order to differentiate the organizational structure from the report structure. This kind of approach increase the flexibility of the system because a report can be defined in a away that it gather data following a new structure created by the user. This can be useful in some cases where the user want to include or exclude specific places in a report.

PLACE-FIGURE-TIME_STAMP

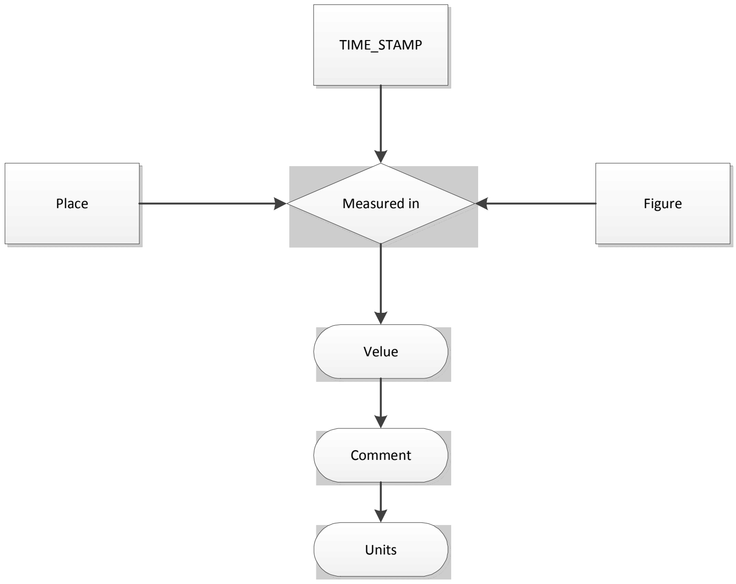


Figure 25 – ER PLACE-FIGURE-TIME_STAMP

The relation presented before as PLACE-FIGURE in association with a time stamp define a value, this value will include not only the measured values, but also targets defined by the administrator, this targets can be generated manually or embed in the business logic in the server,

The entity relations model is simple view of the system capabilities, it does not represent all the constraints and special features that should be included. These constraints will be presented with the physical Database Model. Based in the existing know-how and in the fact that it is an open source product, we establish that the database system that we are going to use is POSTGRES. This database system is a open source product and so it can be supplied directly in the software package without additional costs to the costumer. The system was designed to work with any kind database system using simple SQL instructions. Keeping in focus that the acquisition of a commercial system will increase the costs to the end costumer we decide to use the Theory presented by Joe Celko [16], this theory explain a method to manage tree structures using simple SQL statements in Relational Databases.

According with this model we start designing the Physical Model,

Constraints

Place Type Constraint

To define a model to prevent that the user don´t introduce non consistent structural Places, it was defined a heritage model based on the field PLACE_TYPE, preventing for example the insertion of a PLACE 1 of the type PLANT under a PLACE2 from the type OFFICE. This restriction originates two tables named T_PLACE_LEVEL and T_PLACE_LEVEL_TREE, in the first we store all the available place types and in the second we store the restrictions between them. We must consider that this relation cannot follow a simple Parent-Child logic. For example an Office can be inside a building and also inside a plant.

The physical places are represented in the table T_TREE_NODE, referring to a defined place type. In the table T_TREE_NODE is important to refer two of the fields : LOW, HIGH, as stated before this fields will allow the management and presentation of a tree structure using only basic SQL statements. In the diagram below we can see how they are associated with the values.

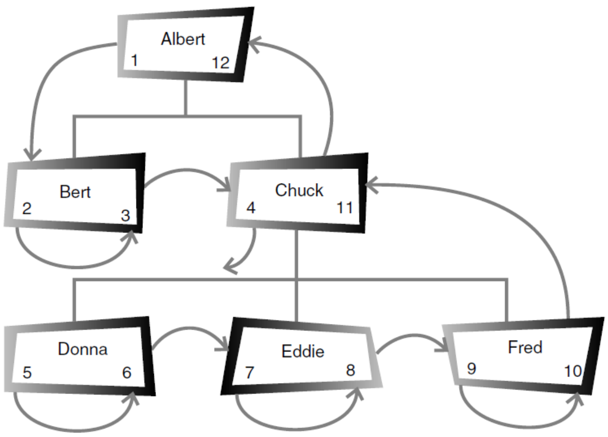


Figure 26 – Tree Structure Delkos Theory

Each value in the table T_TREE_NODE is referenced by two number denominated low and high, this values allow the system to place a SQL pure statement that retrieve all the information from the tree structure. This have one disadvantage that should be taken into consideration while building the business logic in the server, every time that the structure is changed the values in the fields Low and High should be updated.

Reports Definition

To define the reports, we create a separated tree structure, presented by the table T_REPORT, this table contains a reference to the table TREE_NODE linking reporting units with TREE_NODEs. The user can manage several reports creating them without respect the previous rule established by the table T_PLACE_TYPE. Also the definition of the time period of the report is defined here.

Figure Constraints

The table T_Figure store all the figures that the software can measure and report, this table represent all the information related with one figure and also associations between them. One of the relevant fields in this table refers to the measuring unit of the figure. As presented in the chapter 5, the multi-unit system enables the user to select different units according with their own necessities. The table T_UNIT_FACT all the possible relations between units that are stored.

Each figure has an associated unit that is used to store the measured value in the table T_VALUE, if the user chose to use a different one the system will automatically convert it to the system unit. In the table T_VALUE is stored not only the measured value but also the expected forecasts generated by the business logic or by a specific user. The periodicity define the creation of time stamps that represent a moment or period in a time line, The periodicity is defined according with the figure in a specific tree node, allowing different granularity in the collected data, when a report is generated this periodicity must represent a constraint in the maximum granularity of a report. A unit can be defined using multiple factors and relations that are stored in the table T_UNIT_DEF.

These constraints were taken into consideration in the development process of the database model. The ANNEX A present the SQL code associated with this constraints.

5.2 Database Model

The general model presented bellow intends to show all the tables that the system use, after we will present several isolated groups of tables to show specific constraints that were taken into consideration. This model can be adjusted according with special requirements, but the basic structure should be maintained. In order to promote a better visualization of the presented figures they are presented in Annex B in a magnified view.

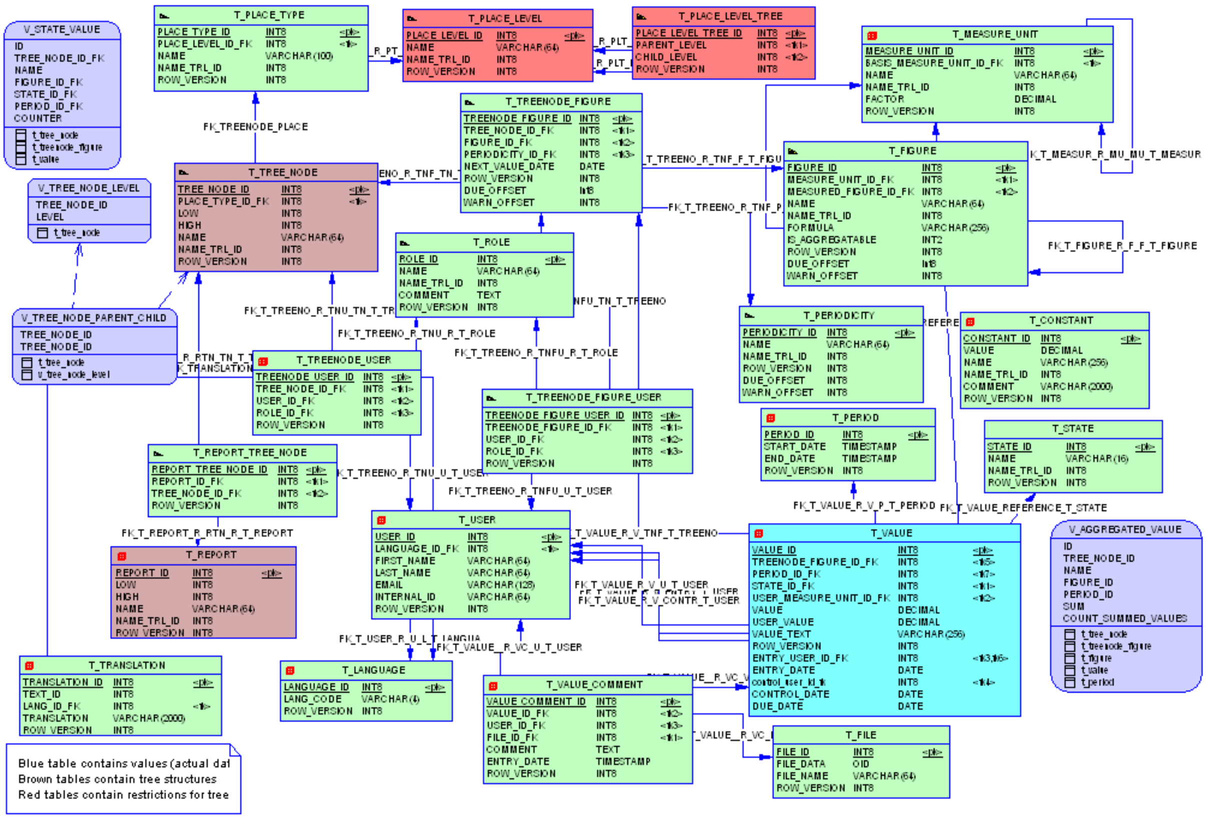


Figure 27 – Database General

Organizational Structure

The organizational structure is handled using the group of tables presented bellow, it prevents that a TREE_NODE representing a physical place is created only if it respect the organizational structure.

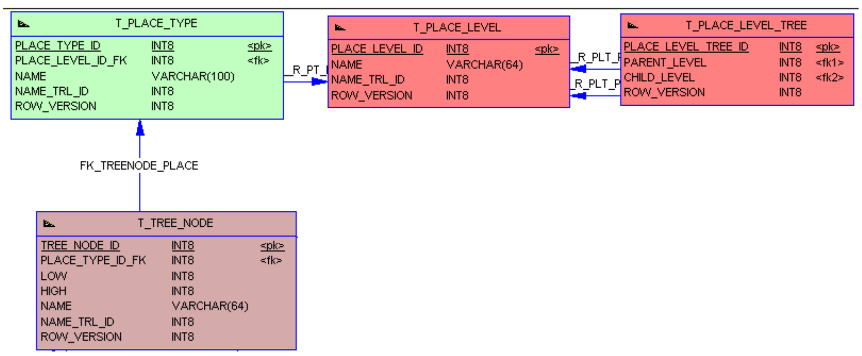


Figure 28 – Database Tree Structure Restrictions

The organizational structure is stored in the two red tables.

Figures and Treenodes association

The schem below present the association between Tree nodes (places) Figures and users, this is the core part of the database because it track and reference all the data to a specific place,

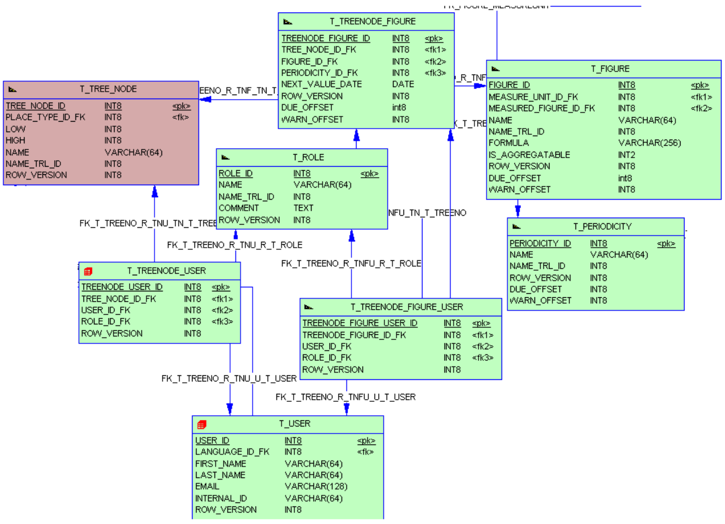


Figure 29 – Database Figures and Treenodes

The data gathered in this group of tables is conected with a table T_VALUE that store all the values in the database associating it with a time period, Bellow represent the table T_VALUE in conection with some adtional table that manage the periods to which the values refers and also comments inserted by the users to justify the inserted values.

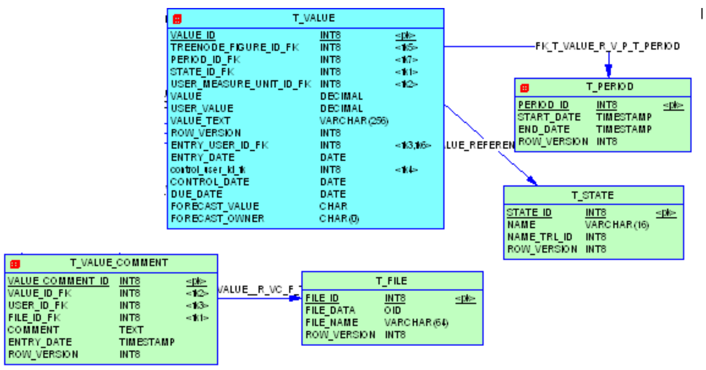


Figure 30 – Database value storage

Multi-Unit System

This set of tables agregate the relations between units in order to allow the business logic to evaluate and store units and evaluate compatible relations than can be created.

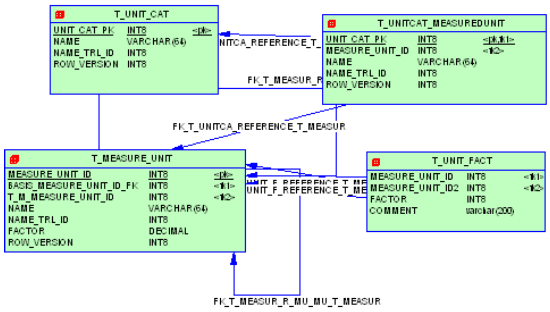


Figure 31 – Database Multi-unit system

In the Annex A, we will find the SQL constraints related with the database generation, and in the Annex B is presented a resume of all the tables from the model,

5.3 Business Logic

As stated before all the procedures that manage the transactions with the database are stored in a server cluster, in there we find all the business logic behind the system itself. The decision of implement all the business logic in a server cluster is based in the know-how of SOLVE-IT implementing this kind of solutions.

Using the server as a middle point for all the transaction between the client and the database improves the flexibility of the system to face upgrades and implementation of new features.

Embedded in the business logic we will find all the functions related with the data management, user permissions based in roles, operation-cue for each user, multi-unit system analysis, graph definition and generation, reports creation, goals definition based in available rules and other general functions,

User Permissions

A module will analyse and evaluate, the role of each user in relation with a place or figure, this will create the appropriate menus in order to only allow the user to see the data which is owner or responsible for.

Operation-Cue

The system will analyse the operation cue of each user in order to present to him all the tasks that should be accomplished.

Graphs and Reports

The graphs and reports are generated in the client using the BIRT plug-in, nevertheless the data gathering process is handled by the business logic unit. The server also store all the logic behind the graphs adaptation according with the different units.

Multi-Unit System

All the information and transformation inherent to the multi-unit system is handled by the business logic providing to the client for example compatible units for a special figure.

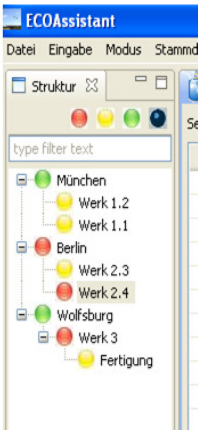
Goals Definition

The task of define a goal to a figure or group of figures is handled by the business logic, it can integrate several methods to produce a goal, based either in an input from the user or in a statistical analysis of the previous data.

5.4 Graphical User Interface (GUI)

The GUI design is important in order to show the basic behaviour and organization of the data like it is going to be presented to the user. Following the principles of agile development the presented screenshots represent already functional parts of the software. The GUI presentation in this report will focus especially in the data editor where the user can introduce the data measured and also in the reporting section where the gathered data is presented. Some of the functionalities presented in this chapter still not available at the time of the conclusion of this report. The presented figures are included in the ANNEX C in a magnified view.

In the Figure below we can see the tree structure created to an organization, it allows the user to navigate over all the facilities previously defined. The available figures will be presented according with this selection,



The Figure bellow presents a simple data insertion of multiple figures, based in the user login and also in the selected place. The colour scheme used in the structure and also in the values itself represents the state of the value. The colour next to each value represents its status according with the definition of the roles of each user.

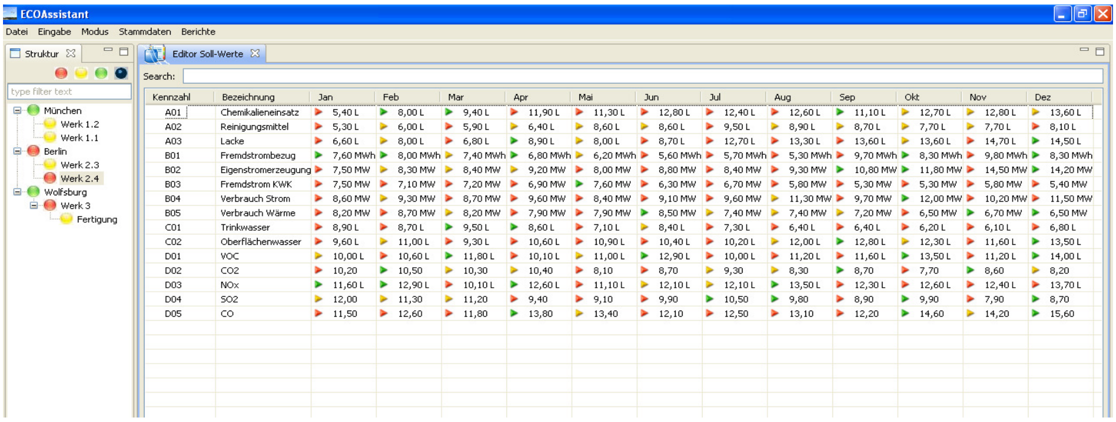


Figure 33 – Data Insertion (Prototype GUI)

The graphs bellow represent an example of a possible report created by the software, currently the multi-unit system and also the auto adjustment of the graphs axis are not implemented.

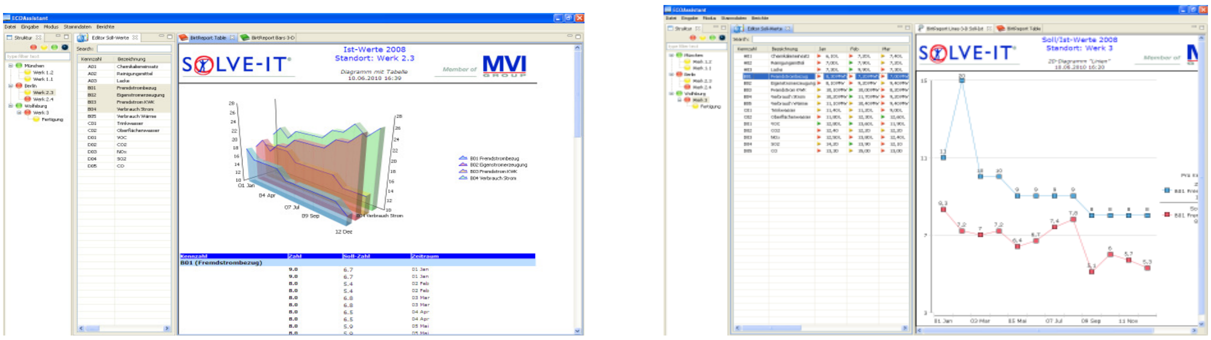


Figure 34 – Graphical representation (GUI Prototype)

5.5 Overview

The prototype defined in this chapter intent to present a example of integration of all the requirements and conclusions gathered along the previous chapters. The creation of a database model that follow all the key aspects (organizational structure, multi-unit system , user management , data aggregation) define a real solution for the carbon accounting issue . The application intends to cover all the main aspects of the deming cycle promoting a continuous visibility over the gathered data. The approach that was used make it suitable to any kind of organization and let the user define which kind of granularity he intend to report and enable a flexible method to create reports in order to meet different requirements.

6 Conclusions and Recommendations for further work

6.1 Conclusions

This project approaches several fields in order to establish and define a model of a Carbon Accounting Software. The acquisition and report of environmental control units is currently a main issue in the behaviour of the commercial organizations. The diversity of environmental figures to measure establishes some special requirements that should be considered in the development of a reporting solution. The results presented do not have a clear meaning if they are not presented in the correct way. A system should be able to adapt the data according with the customer requirements in order to improve its usability and accuracy, nevertheless all the gathered data should be stored in a way that permits to create reports or presentations that match the standard requirements currently established (GRI, CDP) or any other standard that can be created in future, This kind of data transformation requires a well defined method to store the data that keep as much references to a single value as possible. The defined database model matches the requirements of a CAS, handling the data related with a commercial organization, it can be used by organizations of any type since it is completely customizable according with any organizational or profit center structure. The flexibility of the system regarding the creation of new figures to measure and grouping them in different structures allow the costumer to create and define multiple data profiles defining reports based on them. Several questions have been presented regarding the presentation of multiple figures in graphs concerning the different ranges of the measured figures and how they can be transformed in order to present multiple figures in the same view. The multi-unit system represent a main feature in the flexibility of the system allowing different views from the same data in order to enable an easy insertion process and also a more flexible reporting construction. The fact that the system can handle several units for the same value enables the creation of specific ratios for an organisation keeping also the data in a standard format. The presented methods concerning the data gathering and also the data analysis in order to produce reports present a reliable and customizable solution to store and report all the figures related with the environment field. The flexible reporting system integrated with the reports optimization process can produce a wide range of reports, The specific way that was used in the database design make it suitable to this kind of report, the data is gathered in a structured way enabling the creation of relations between the different figures, wither using the Multi-Unit system or through the categorization of figures,

6.2 Recommendations for further work

The integration of the current standards (GRI, CDP) with the CAS system is currently made in only one direction, the software applications support the established standards. There is not any reference in the current standards about the software behaviour in the handling and reporting of environmental data. , A future project that integrates CAS and reporting standards in a network will bring the treatment of the emissions and disposals to a new level where it will be possible to the organization to impute to their clients the emissions that are related their commercial relations, creating a transparent supply-chain structure for the environmental figures. The establishment of this kind of network will promote and unification in the outputs provided by the different software solutions available in the market .

To the developers that intend to produce applications or define methods regarding this problematic we advice a wide analysis of the data that should be stored and reported, only this analysis will give to the developer the required global view to produce a cross-sector solution. Considering the case of specific solutions targeted to a specify group of costumer is important to point out the need of a general output and report solution that follow all the presented standards.

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ANNEX A: SQL Constraints

```
alter table T_FIGURE
  add constraint FK_T_FIGURE_R_F_F_T_FIGURE foreign key (MEASURED_FIGURE_ID_FK)
    references T_FIGURE (FIGURE_ID)
    on delete restrict on update restrict;

alter table T_FIGURE
  add constraint FK_FIGURE_MEASUREUNIT foreign key (MEASURE_UNIT_ID_FK)
    references T_MEASURE_UNIT (MEASURE_UNIT_ID)
    on delete restrict on update restrict;

alter table T_MEASURE_UNIT
  add constraint FK_T_MEASUR_R_MU_MU_T_MEASUR foreign key (BASIS_MEASURE_UNIT_ID_FK)
    references T_MEASURE_UNIT (MEASURE_UNIT_ID)
    on delete restrict on update restrict;

alter table T_PLACE_LEVEL_TREE
  add constraint FK_T_PLACE__R_PLT_PL_T_PLACE_ foreign key (PARENT_LEVEL)
    references T_PLACE_LEVEL (PLACE_LEVEL_ID)
    on delete restrict on update restrict;

alter table T_PLACE_LEVEL_TREE
  add constraint FK_T_PLACE__R_PLT_PL2_T_PLACE_ foreign key (CHILD_LEVEL)
    references T_PLACE_LEVEL (PLACE_LEVEL_ID)
    on delete restrict on update restrict;

alter table T_PLACE_TYPE
  add constraint FK_T_PLACE__R_PT_PL_T_PLACE_ foreign key (PLACE_LEVEL_ID_FK)
    references T_PLACE_LEVEL (PLACE_LEVEL_ID)
    on delete restrict on update restrict;

alter table T_REPORT_TREE_NODE
```

```
  add constraint FK_T_REPORT_R_RTN_R_T_REPORT foreign key (REPORT_ID_FK)
    references T_REPORT (REPORT_ID)
    on delete restrict on update restrict;

alter table T_REPORT_TREE_NODE
  add constraint FK_T_REPORT_R_RTN_TN_T_TREE_N foreign key (TREE_NODE_ID_FK)
    references T_TREE_NODE (TREE_NODE_ID)
    on delete restrict on update restrict;

alter table T_TRANSLATION
  add constraint FK_TRANSLATION_LANGUAGE foreign key (LANG_ID_FK)
    references T_LANGUAGE (LANGUAGE_ID)
    on delete restrict on update restrict;

alter table T_TREENODE_FIGURE
  add constraint FK_T_TREENO_R_TNF_F_T_FIGURE foreign key (FIGURE_ID_FK)
    references T_FIGURE (FIGURE_ID)
    on delete restrict on update restrict;

alter table T_TREENODE_FIGURE
  add constraint FK_T_TREENO_R_TNF_P_T_PERIOD foreign key (PERIODICITY_ID_FK)
    references T_PERIODICITY (PERIODICITY_ID)
    on delete restrict on update restrict;

alter table T_TREENODE_FIGURE
  add constraint FK_T_TREENO_R_TNF_TN_T_TREE_N foreign key (TREE_NODE_ID_FK)
    references T_TREE_NODE (TREE_NODE_ID)
    on delete restrict on update restrict;

alter table T_TREENODE_FIGURE_USER
  add constraint FK_T_TREENO_R_TNFU_R_T_ROLE foreign key (ROLE_ID_FK)
    references T_ROLE (ROLE_ID)
```

```
    on delete restrict on update restrict;

alter table T_TREENODE_FIGURE_USER
  add constraint FK_T_TREENO_R_TNFU_TN_T_TREENO foreign key (TREENODE_FIGURE_ID_FK)
    references T_TREENODE_FIGURE (TREENODE_FIGURE_ID)
    on delete restrict on update restrict;

alter table T_TREENODE_FIGURE_USER
  add constraint FK_T_TREENO_R_TNFU_U_T_USER foreign key (USER_ID_FK)
    references T_USER (USER_ID)
    on delete restrict on update restrict;

alter table T_TREENODE_USER
  add constraint FK_T_TREENO_R_TNU_R_T_ROLE foreign key (ROLE_ID_FK)
    references T_ROLE (ROLE_ID)
    on delete restrict on update restrict;

alter table T_TREENODE_USER
  add constraint FK_T_TREENO_R_TNU_TN_T_TREE_N foreign key (TREE_NODE_ID_FK)
    references T_TREE_NODE (TREE_NODE_ID)
    on delete restrict on update restrict;

alter table T_TREENODE_USER
  add constraint FK_T_TREENO_R_TNU_U_T_USER foreign key (USER_ID_FK)
    references T_USER (USER_ID)
    on delete restrict on update restrict;

alter table T_TREE_NODE
  add constraint FK_TREENODE_PLACE foreign key (PLACE_TYPE_ID_FK)
    references T_PLACE_TYPE (PLACE_TYPE_ID)
    on delete restrict on update restrict;
```

```
alter table T_USER
  add constraint FK_T_USER_R_U_L_T_LANGUA foreign key (LANGUAGE_ID_FK)
    references T_LANGUAGE (LANGUAGE_ID)
    on delete restrict on update restrict;

alter table T_VALUE
  add constraint FK_T_VALUE_REFERENCE_T_STATE foreign key (STATE_ID_FK)
    references T_STATE (STATE_ID)
    on delete restrict on update restrict;

alter table T_VALUE
  add constraint FK_T_VALUE_REFERENCE_T_MEASUR foreign key
(USER_MEASURE_UNIT_ID_FK)
    references T_MEASURE_UNIT (MEASURE_UNIT_ID)
    on delete restrict on update restrict;

alter table T_VALUE
  add constraint FK_T_VALUE_R_V_CONTR_T_USER foreign key
(CONTROL_USER_ID_FK)
    references T_USER (USER_ID)
    on delete restrict on update restrict;

alter table T_VALUE
  add constraint FK_T_VALUE_R_V_ENTRY_T_USER foreign key
(ENTRY_USER_ID_FK)
    references T_USER (USER_ID)
    on delete restrict on update restrict;

alter table T_VALUE
  add constraint FK_T_VALUE_R_V_P_T_PERIOD foreign key (PERIOD_ID_FK)
    references T_PERIOD (PERIOD_ID)
    on delete restrict on update restrict;

alter table T_VALUE
  add constraint FK_T_VALUE_R_V_TNF_T_TREENO foreign key
(TREENODE_FIGURE_ID_FK)
```

```
    references T_TREENODE_FIGURE (TREENODE_FIGURE_ID)
    on delete restrict on update restrict;

alter table T_VALUE
  add constraint FK_T_VALUE_R_V_U_T_USER foreign key (ENTRY_USER_ID_FK)
    references T_USER (USER_ID)
    on delete restrict on update restrict;

alter table T_VALUE_COMMENT
  add constraint FK_T_VALUE__R_VC_F_T_FILE foreign key (FILE_ID_FK)
    references T_FILE (FILE_ID)
    on delete restrict on update restrict;

alter table T_VALUE_COMMENT
  add constraint FK_T_VALUE__R_VC_U_T_USER foreign key (USER_ID_FK)
    references T_USER (USER_ID)
    on delete restrict on update restrict;

alter table T_VALUE_COMMENT
  add constraint FK_T_VALUE__R_VC_V_T_VALUE foreign key (VALUE_ID_FK)
    references T_VALUE (VALUE_ID)
    on delete restrict on update restrict;
```

ANNEX B: Database Model

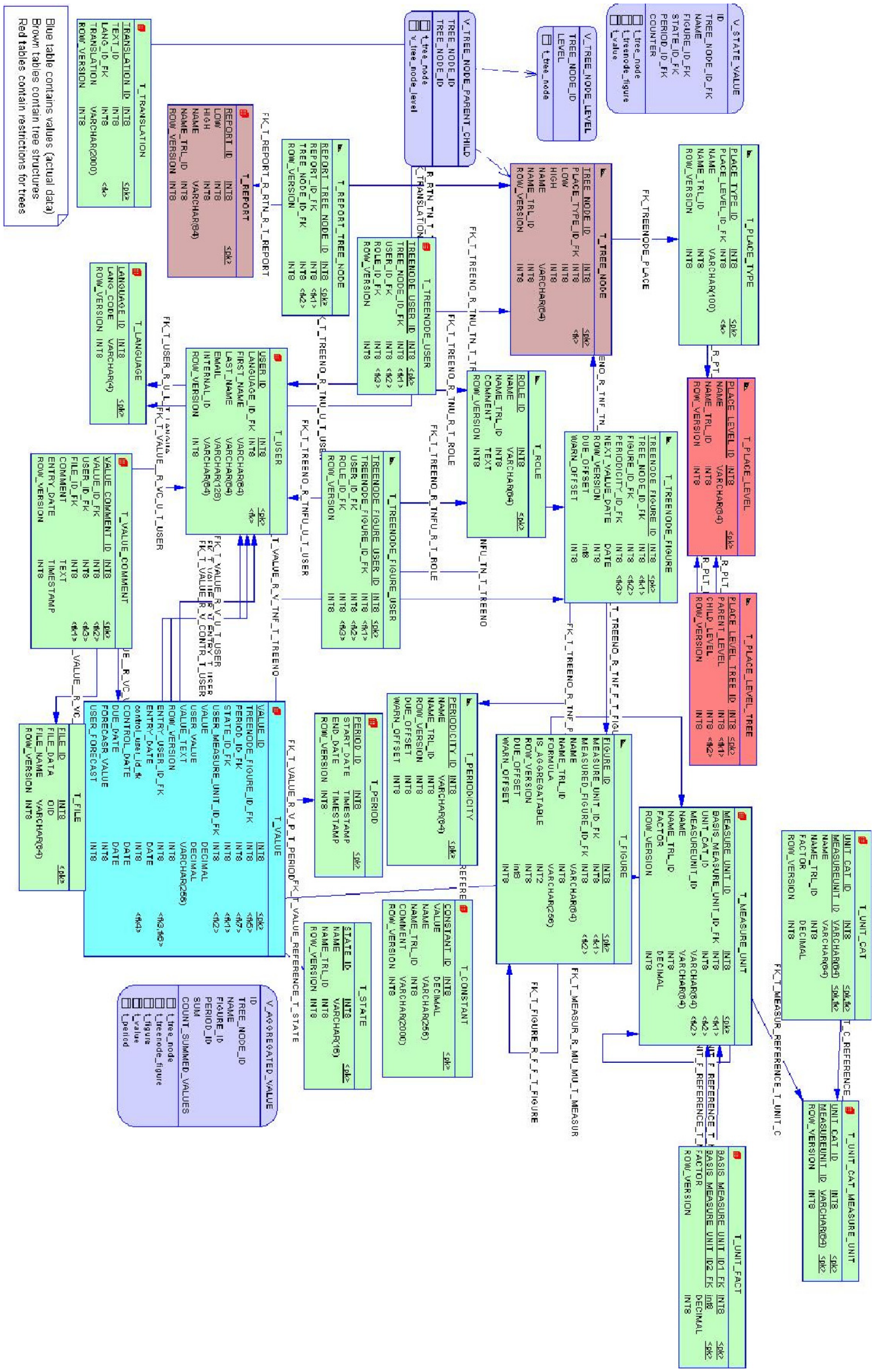

Figure 35 – Database General

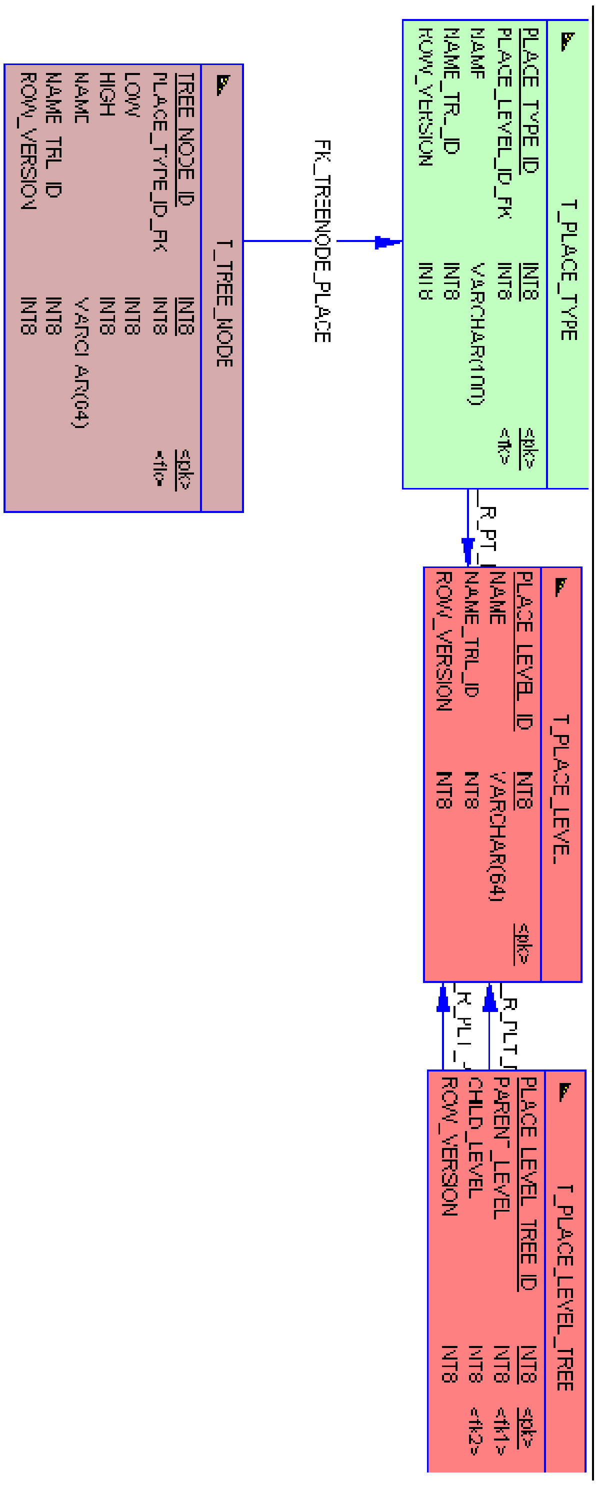

Figure 36 – Database Tree Structure Restrictions

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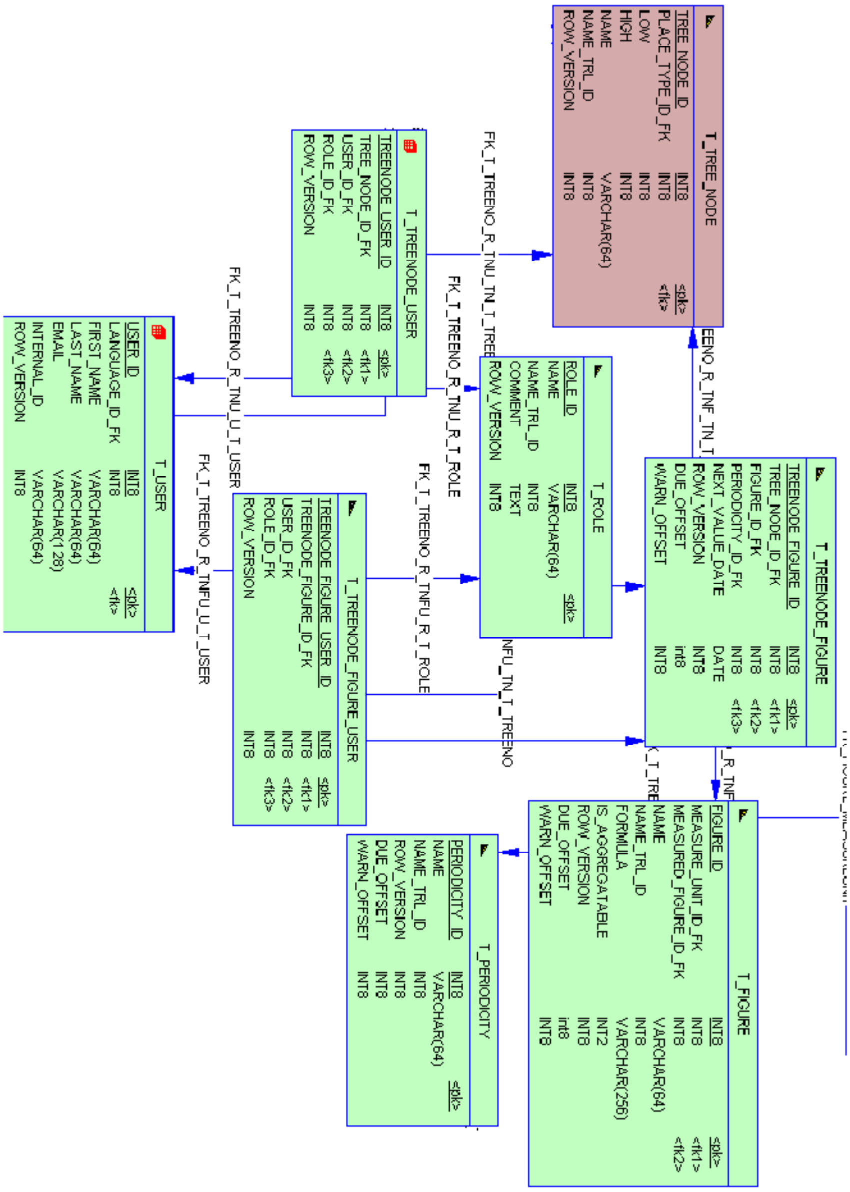


Figure 37 – Database Figures and Treenodes

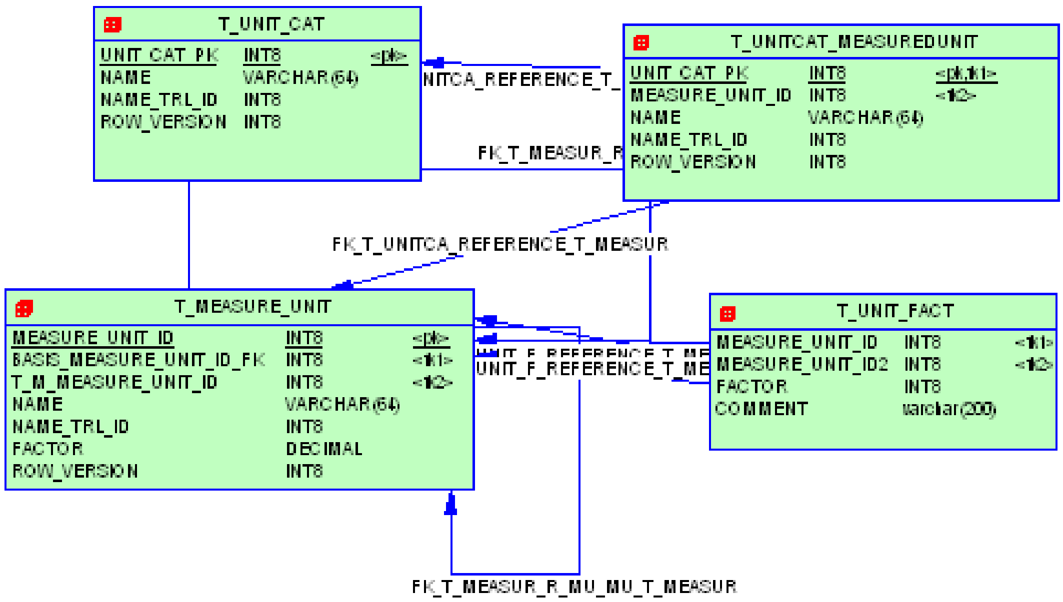


Figure 38 – Database Multi-unit system

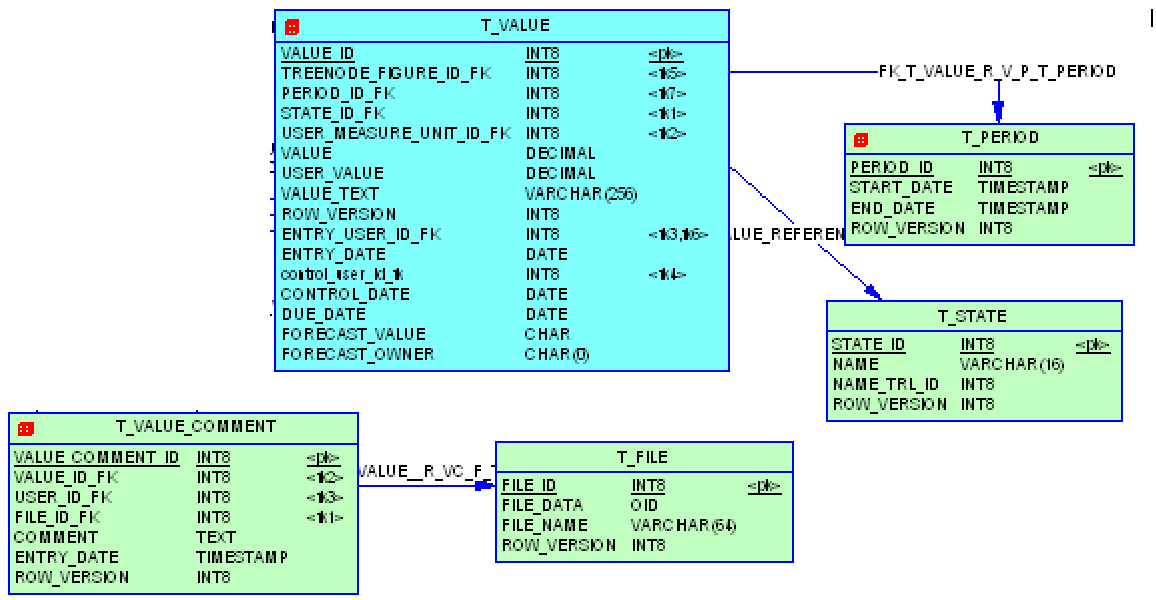


Figure 39 – Database value storage

ANNEX C: GUI

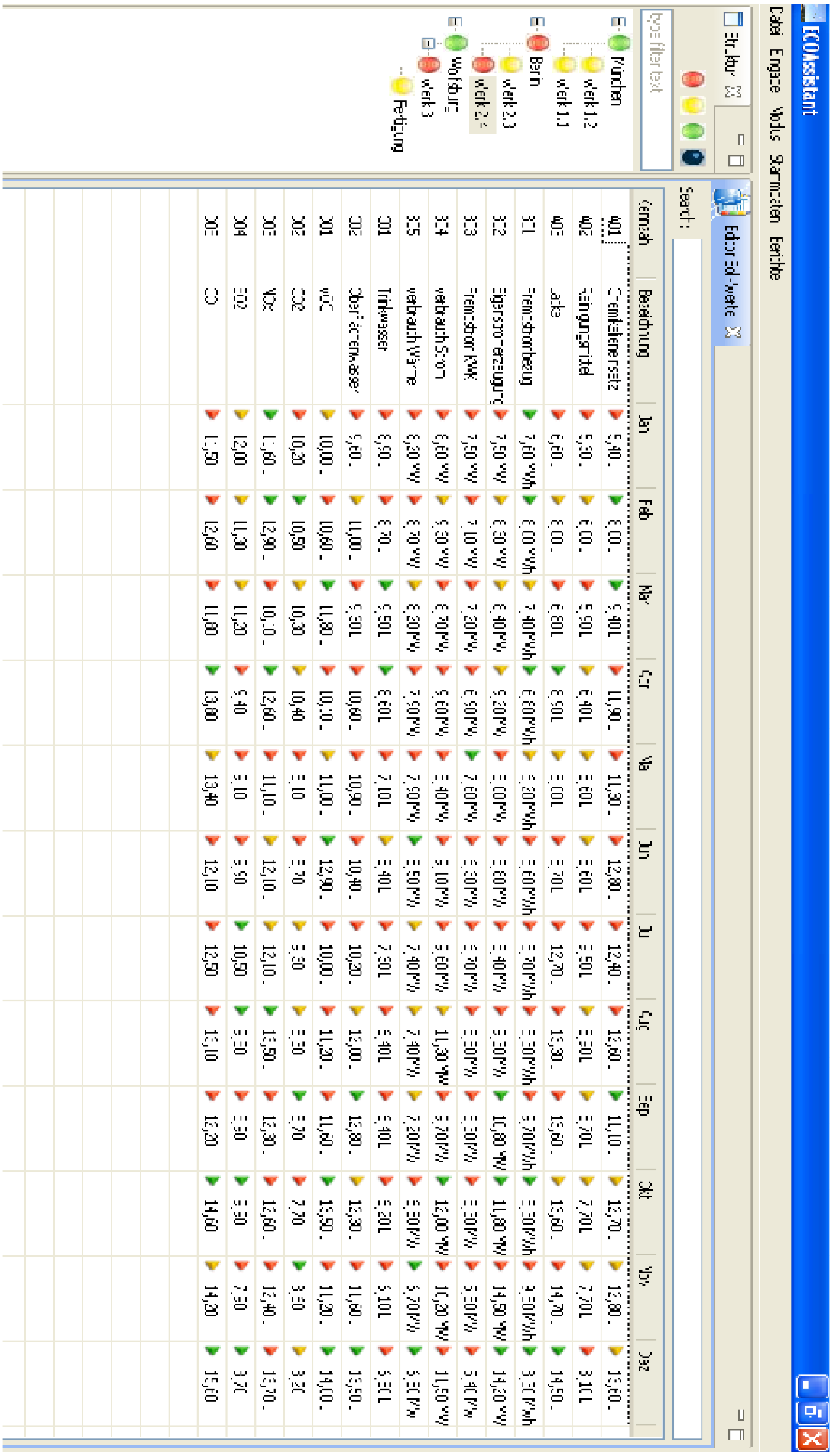
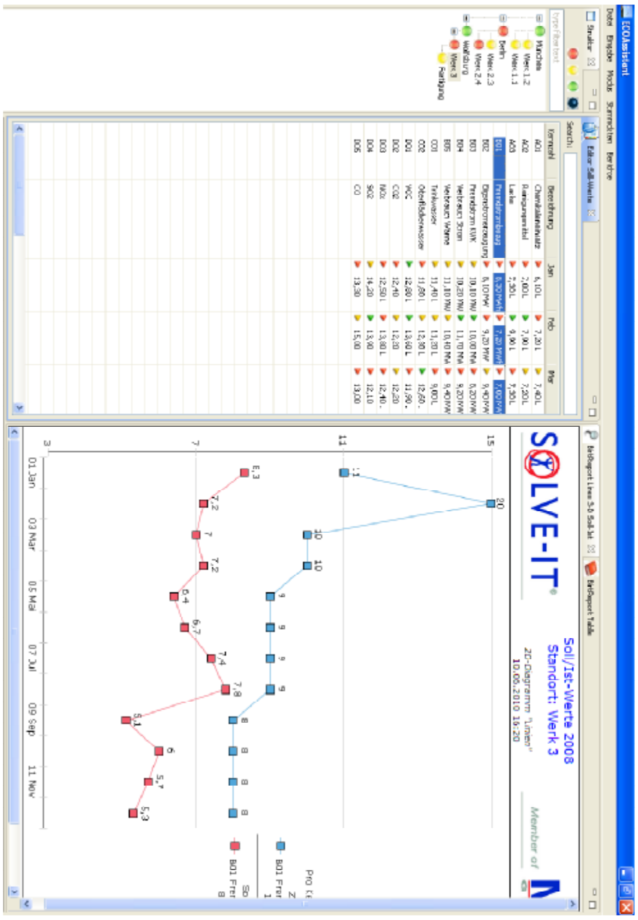


Figure 40 – Data Insertion (Prototype GUI)



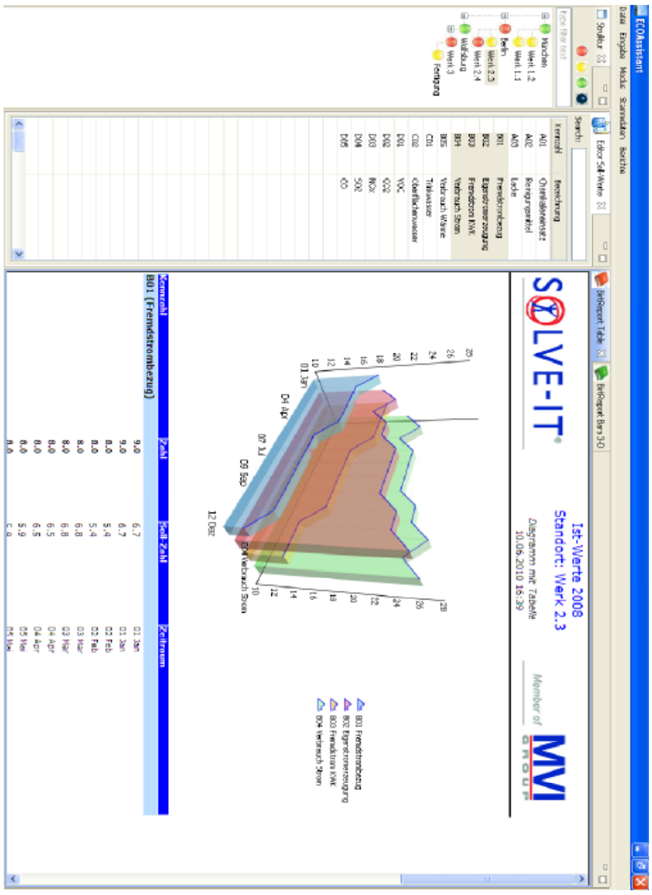


Figure 41 – Graphical representation (GUI Prototype)