ANR-06-RGCU-002

COMMUNIC

Deliverables
L3 : Functional Program of the Digital Model

Version 10/12/2010

Collaboration using the Multi-Purpose Digital Model and Concurrent Engineering

Contents

page

Presentation of deliverable L3

COMMUNIC: one memo, three deliverables

The COMMUNIC project

The research project is called COMMUNIC, for *COllaboration par la Maquette Multi-Usages Numérique et l'Ingénierie Concourante (Collaboration using the Multi-Purpose Digital Model and concurrent engineering)*. It was selected by **ANR** (Agence Nationale de la Recherche) following a call for proposals in 2006.

This project was approved by the **ADVANCITY Competitiveness cluster.**

The project was **begun in 2007** and lasted 3 years.

Object

Its purpose is to foster the development of collaborative work in infrastructure projects through the use of an information model (IM).

Partners

The project partners are:

- **Engineering**: EGIS and Setec TPI.
- **Contractors** Bouygues Construction, Vinci Construction France, Eiffage TP.
- **Research Centers** and **Academic Partners**: CSTB, the Ecole Polytechnique's Management Research Center, LCPC, University Paris Est, and IREX.

Overview of work done by COMMUNIC

The research conducted under the COMMUNIC research project is the object of this memo, which summarizes the project's progress and results.

To make this thesis more practical to use, we have completed it with three deliverables that:

- describe our work more fully,
- provide unique perspectives on our conclusions.

COMMUNIC project deliverables

The table below shows the 3 deliverables:

Deliverable	Title	Mission	Contents
L1	*Global model*	Describe the **technological and organizational model** which will support collaborative work through a shared digital model	Overall description of the model. Expected values and uses. Structuring of information and its circulation. Adaptations of the organizations. Redistribution of responsibilities.
L2	*Recommendations for implementation of the digital model*	List of **recommendations** for stakeholders.	Tools. Projects. Companies. Construction sector. Change management.
L3	*Functional program of the digital model*	Aimed at software publishers who will have to adapt or create software allowing use of the digital model.	Projects concerned. Proposed system with the expected features, architecture, data model and standardization.

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Content of deliverable L3 chapters

Chapters

The table below shows the chapters:

Chapter	Title	Contents
A	*Background*	Organizations constituting the environment of the IM. Characteristics of the disciplines involved. Projects to be selected to implement the IM.
B	*Functions*	Six major functions that allow handling of an infrastructure project.
C	*Architecture*	Structure of features to draw up a software architectural schema and distribute functions among the tools.
D	*Software components*	Characteristics of each type of software in the schema which appear to be essential.
E	*Data Model*	Basic elements of a data model in order to install an IM according to the global COMMUNIC model.
F	*Roadmap to a COMMUNIC exchange standard*	Outline of action plan which must be implemented to have an exchange standard, data model and neutral format which determine the global model.

Appendices

To facilitate the reading of the document, we have attached:

- Discipline-specific software packages.
- Report of Task 4: Experience-action *in vivo.*
- Analysis of the transposition of IFC.

Reading Aids

Acronyms

The acronyms used frequently in the document are explained below.

Acronym	Meaning
APS	Short preliminary project
AVP	Preliminary project
BE	Design Department
BIM	*Building Information Modelling*
BTP	Construction industry
CAD	Computer Aided Design
GCC	General Conditions of Contract
EC	External Control
D & B	*Design and build*
DAO	Computer Aided Design
DCE	Tendering package
GED	Electronic Document Management
IFC	*Industry Foundation Classes*
KM	*Knowledge management*
IM	Information model
MOA	Client
MOE	Principal contractor
MOP	French public building procurement [law]
PLM	*Product Life Management*
PPP	Public Private Partnership
R & D	Research and development
SaaS	*Software as a Service*
SDK	*Software Development Kit*
DBMS	Database Management System
GIS	Geographic Information System
STEP	*Standards for the Exchange of Product model data*
TP	Public Works

Glossary

Definitions (taken from *www.wikipedia.fr*) of the discipline-specific terms necessary for understanding the present document are given in the table below.

Term	Definition
Benchmarking	**Benchmarking** is a quality management technique that consists in studying and analyzing the management techniques and methods of organization of other companies to draw inspiration from them and select the best.
Building Information Modelling	BIM covers the design data production and management processes through all stages of building design.
Building SMART	The French building industry digital model website. http://www.buildingsmart.fr/
Clash, Conflict, Interference	These three terms are used interchangeably in the deliverables and the memo.
Geolocation	**Geolocation** or **georeferencing** is a way of positioning an object (a person, information, etc.) on a map using its geographic coordinates.
IFC	The **IFC** (*Industry Foundation Classes*) format is an object-oriented file format used by the building industry to exchange and share information between programs.
Open Source	The ***open source*** designation applies to software of which the license satisfies strict criteria established by the Open Source Initiative, namely the possibility of unrestricted redistribution, access to source code and derivative work. Free software is often called "open source" because open source-compatible licenses include free licenses as defined by the FSF. The term *open source* competes with the term "*free software*" recommended by the FSF. The term "freeware" means software that is free of charge but not necessarily open or unrestricted.
Standard	An official **standard** (industrial) is a frame of reference published by a standards organization such as AFNOR, CEN, ISO, OASIS
	A de facto **standard** [...] is a documented common baseline intended to harmonize the activity of a sector.
STEP	The **standard for the exchange of product data**, **STEP** or **ISO 0303,** covers the representation and exchange of product data and is aimed at integrating product design, development, production, and maintenance processes.

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A - Context

A1 - Organizational context

Several factors have come about lately to "change things" and promote the use of IM tools.

Contractual schemas for procurement

Major infrastructure projects (road, rail, industrial) are currently implemented by 3 types of contracts shown below.

Type 1: Design - Bid - Build

In Type 1, "Design - Bid - Build", the design is done **upstream**.

The construction company then determines the most suitable methods to execute a given project at lowest cost. Work contracts can even be assigned in **separate batches** (metal, concrete, etc.).

Type 2: Design & Build

Type 2 is called "Design & Build" (D & B). It brings together **the whole chain** from design to completion with a single contractor.

Type 3: Concessions or PPP

In Type 3, "concessions" or "PPP", the contractor is all at once client, designer, builder and operator for a fixed term. We also talk about **BOT** (Build - Operate - Transfer). This is the **most integrated** type of design.

At the end of the concession, the concessionaire returns the structure to the concessionary authority.

Development of integrated projects

Types 2 and 3 are rapidly gaining popularity...

The first type of contract is most prevalent. However, Types 2 and 3 are rapidly gaining popularity, and are chosen to handle the **biggest infrastructure projects** (highways, railroads, stadiums, various complexes, etc.).

... and are most favorable to concurrent engineering

In the classical Type 1 contract, changes in the project are reflected on a set of 2D drawings. This requires a long process of requests for change and approvals, leading to high costs and long completion times.

Types 2 and 3, however, bring design, choice of construction methods, equipment and operating modes together in the same entity. In integrated design (contract Types 2 and 3), studies may be **anticipated,** and the services and subcontractors become involved more **upstream.** They are therefore most favorable to the application of an integrated tool of the IM type.

Acceleration of data exchange process

Today, the acceleration of exchanges means a large volume of information (text or drawing files) is being carried by e-mail.

A need for fluidity of exchanges...

E-mail systems may be saturated. The ever-increasing volume of information therefore also creates a greater need for fluidity of exchanges.

... partially handled by EDM ...

On major infrastructure projects (highways, high speed rail lines, etc.), the introduction of an **EDM** simplified management, and channeled the flow of information. However, it did not provide an answer to the question of how to **represent** the project in terms of manipulable and parametric objects.[1]

... and addressed by the IM

The growth of Type 2 and 3 contracts is a good opportunity for the adoption of an IM tool, which alone is capable of **ensuring an integrated approach** in a limited time with a multi-criteria analysis of the performance required by the specifications.

Organization of the sector

In industry (in particular automobiles, aerospace, shipbuilding), the design process is organized by a **powerful stakeholder** who chooses his tools and provides them to partners and subcontractors.

The diversity of stakeholders was a hindrance to the sharing of tools

In construction, there are very many stakeholders such as clients, engineering firms, companies or suppliers. **None of them** is in a position to choose a tool or a standard and impose it on the others.

They therefore share **no common tools** apart from the basic office software packages on the market and general design software. This also explains the large numbers of software packages used, a number that is in fact an obstacle to the emergence of common tools.

[1] *A parametric modeling system is a system that records not only the explicit geometry of the design object ("parametric object" or "'current instance), but also a mechanism to reassess when the parameters are modified ("design process"," constructive gestures "or "parametric specification"). http://www.lisi.ensma.fr/fr/equipes/idd/geometrieparametrique.html*

A2 - Discipline-specific context

2D/3D Design

Overview

The installation base of 2D or 3D design software covers several t**housands of licenses** in France. However, there are only a **few IM products** in design departments, engineering firms and companies involved in major linear infrastructure projects. The stakeholders in the construction industry (architects, engineering firms, etc.), on the other hand, have commercially-available tools sui**ted** to their profession.

Civil engineering drawings are mostly prepared using **general-purpose software packages, m**ainly Autocad (published by Autodesk). Their use may or may not be accompanied by additional "discipline-specific" applications for road alignments, for example, for drawings of reinforcements in concrete, or for the layout of steel frames. This specialized software brings together all the expertise of a domain, and must be preserved or duplicated in the **new tool**.

Many businesses still design in 2D

The current design tools have been designed to automate the old methods of design, which were manual.

Some have therefore exploited the **linear** characteristic of certain infrastructure (roads, railways, etc.), and the design is still "3 times 2D". They work first on the **alignment**, then **fit on** a longitudinal profile, and finally attach cross sections. Each step is thus done in 2D.

For other infrastructure projects, calculations are sometimes done on a **surface** (no preferred horizontal axis). The design elements are always longitudinal profiles, cross sections, and cross-sectional profiles.

Methods of execution have been adapted to these design principles with, for example, **setup of axes,** then the characteristic points of cross sections. The fields designed in this way are thus, for example:

- geometry,
- earthworks,
- drainage,
- pavement,
- longitudinal equipment.

Some designs are done with 3D objects

Some disciplines have had to manipulate 3D objects. The tools that were developed correspond more to 3D design. This applies, for example, to:

- structures,
- operating buildings,
- some equipment of more industrial type.

See the geometric result of design in 3D

The designer always wanted to view his design. Without mentioning physical mock-ups, which were rarely employed, he used:

- **drawings**,
- **perspective drawings**,
- **automatic 3D views** that many software packages have incorporated into their design features,
- **virtual models** which some providers have been offering in real time for over a decade.

This 3D view of the structures designed is not to be confused with the design of 3D volumetric objects to which information is attached. It is this design which the IM can fully exploit.

Integration of environmental data

In addition to the usual bills of quantities or calculations of strength of materials, current projects should incorporate environmental parameters **from the initial design stage.** For example:

- carbon footprint
- thermal performance,
- acoustic performance,
- energy performance,
- impacts on biodiversity,
- land compensation.

These parameters must be quantified and may be used throughout the life of the structure. Therefore the **IM must manage data** which allow these assessments.

Moreover, it is desirable to have the most realistic **virtual representation** possible. It integrates many components with the possibility of simulating / optimizing the functioning of the project during the construction phase or the operation phase.

This leads to a real **monitoring of the structure** throughout its life, which is the very definition of PLM.

Exchange media

Outputs are not reused from one discipline to another

The design process is undertaken **specialty by specialty** ("sector by sector"), with little reuse of the basic geometry or outputs from one discipline to another. For example, geometry is **not connected** to:

- **planning tools** to visualize the phases of the work,
- **price study** software (directly) even though it may include discipline-specific tools for calculating quantities.

Information exchange is done by documents...

The documents supporting the exchange of information are:

- drawings,
- calculation notes,
- reports,
- classifications.

They can be on paper or in electronic form. They have the disadvantage that they group many different items of information. This makes the approval process very cumbersome each time there is a new **version.** Indeed, all the information in the document must be re-validated, including unmodified information.

... the only ones to be managed collaboratively

The only collaborative tool which is frequently used is the **EDM.** It is suited to document exchange.

The **IM must be used** to manage exchanges of information.

Specific needs of geotechnical engineering

Civil engineering works (bridges, linear infrastructure such as roads, rail or river, dams, ports) depend closely, as to their design and choice of construction, on the **geological, hydrogeological and geotechnical** context of the site where they are located.

A strategic element of design

A good knowledge of the geotechnical model is a strategic element for the technical and economic success of the project. This is a very important feature of the infrastructure projects the **IM helps manage.**

Model uncertainties and risks

A methodology should make it possible to develop a geotechnical model with **control of uncertainties and contingencies.** This model makes the geotechnical risk of the project a measurable quantity.

It is built from various data:

- geological maps,
- visual surveys,
- boreholes,
- tests.

This data is then processed by statistical tools, interpolations and extrapolations to **model** the terrain and its characteristics.

Representations suited to the use

The designer and the client need a clear picture of **the spatial organization of materials** constituting the subsoil, as well as their interactions and their characteristics.

Depending on the use to which he wants to put the geotechnical model, each stakeholder uses drawings, cross sections, longitudinal profiles and many tables.

3D object models provided by the IM must be **parameterized** and **specific** to each use, which constitute so many systems:

- view by nature of material,
- extraction conditions,
- conditions of reuse,
- capacity,
- deformability and compressibility,
- hydrogeological network.

The organization of these different views of the model is a challenge for the IM.

A large array of software packages

The IM can exchange data with applications in disciplines from all areas of the sector. There are many of these software packages**,** which meet the specific needs of each discipline.

Application software must evolve to a common standard

When software is systematically complementary, publishers have developed gateways **to exchange** data and results. Given the number of software packages, it is unrealistic to develop and especially to maintain gateways for all desired exchanges .

The challenge is therefore to **develop a neutral standard** shared by the profession, whether it be a data model or an exchange format.

Inventory of application software

Making an inventory of all application software packages used does not contribute to the definition of the global model, architecture or data model proposed by COMMUNIC. Adaptation is done on a case-by-case basis for each program on the initiative of the publisher.

To enable the reader to **assess the diversity, a** list of available software packages has been prepared. It is given in the appendix.

Feedback from Task 4

We have, in Task 4, conducted experiments on the implementation of the global model. They allowed us to establish:

- The extreme difficulty of interconnecting existing software packages.
- Weaknesses in design / authoring software for generating IM objects and attaching information to them.

The report on this Task 4 spells out our findings. It is attached to this deliverable L3.

A3 - Projects involved

Criteria for selecting projects

Below we list the criteria for selecting projects for which it will be recommended to set up an IM.

Collaboration between stakeholders

When a project requires the collaboration of stakeholders to be successful, the use of an IM is unavoidable. Here is some explanations for this:

Factor	Details
Contractual schema	Concessions or D & B are schemas for which the question will soon no longer be asked. For more conventional schemas, the utility is the same. But the larger number of contractors makes its implementation and management less natural. It is the wishes of the client which must be the driving force.
Mode of production of design and / or construction	When teams are located in **different sites,** sometimes very **distant,** there is a risk of segmenting production and missing opportunities for optimization.
Number of specialties brought together to realize the project	The more numerous the specialties are, the more difficult it is to share a single optimization objective of the project. The IM will help in this.
Completion time, which can be respected only with concurrent engineering	Early execution of tasks creates risks that the IM helps to overcome.

It is therefore appropriate to adopt a tool to facilitate communication and exchanges between stakeholders, whether direct or indirect.

Complexity

The complexity of the projects is the first criterion which is considered when judging the benefits of employing an IM. Here are some explanatory factors:

- **Project size,** making it impossible to memorize the whole project, even for an experienced project manager. We must structure the project, and organize and manage partial responsibilities.
- Increasingly sophisticated **techniques** used to build structures.
- **Staging of work** in the urban environment, which is more and more complex.
- **An increasingly large number of stakeholders** , whether directly involved in design and construction, or having an influence on the acceptance or approval of projects.
- Legal, financial or environmental **constraints** which make it necessary to control risks and distribute them among all stakeholders.
- **Sustainable development** which requires comprehensive assessments ranging from construction to operation and even decommissioning.

Type of financing

The financial arrangements for infrastructure projects are increasingly **complex and mixed** (public and private). The cost of the projects must be **followed and understood** by financial professionals who are sharply focused on profitability. They must understand the project and assess the risks.

The IM must therefore be a tool to meet this expectation.

Size

The project size does not affect the optimizations provided by a particular IM in terms of quality, cost and completion time. In fact, small projects, although less publicized than megaprojects, are increasingly being faced with the same **financial and environmental constraints.**

Simulations and evaluations of all kinds have become a necessity, and an IM will help achieve them.

Large complex projects

Large complex projects include, for example, major roads, motorways, railways, canals, tunnels and engineering structures. The following table summarizes their major features.

Characteristic	Details
Size	They often extend over lengths of several **tens, o**r even hundreds **of kilometers**.
Cost	The implementation costs are **very large**, and generally amount to hundreds of millions and in some cases billions of euros.
Environment	Integration into the environment is **strategic** and highly publicized.
Set-up	The legal, financial and contractual set-up is **complex** (concession, PPP).
Time	It takes usually more than a **decade** between initialization and commissioning of the work.
Volume	Since the term "Major Projects" is not officially defined, it is difficult to estimate the corresponding annual investment. However, in France they are estimated at 3 billion euros per year. An estimate at international level is even more difficult to make, but the estimate is several tens of billions of euros annually.

Major projects, driving the change-over towards the IM

The contribution of the IM to these projects is evident vis-à-vis all the above criteria: collaboration, complexity, funding, and size.

The tools developed by other industrial sectors are not directly usable for these major infrastructure projects. Indeed, their **environment differs** strongly. But they are expected to have **similar features,** and many modules or building blocks only have to be adapted.

So without doubt, the major projects that use the IM will appear first in the infrastructure sector.

The expected gains are equal to the investment necessary

The optimization of projects by setting up an IM and concurrent engineering work reduces investment costs. **A gain of 5% would seem to be a minimum.**

With this assumption, we see that the French market for large infrastructure projects alone may provide a **gain of 150 million euros** per year.

This figure shows that stakeholders must be able to fund the developments and investments needed for collaborative work with the IM. It remains to find a mechanism to identify savings and allocate them to the stakeholders who have invested.

The big stakeholders in the profession must be a vector for change

Change must come about through involvement of large companies and engineering firms that are positioned in the market for large projects. There is an opportunity in that there are relatively few stakeholders. A common desire to develop the IM can therefore drive the change

... to allow all stakeholders to benefit ultimately

The goal of collaborative work by the IM should not be limited to major stakeholders. One characteristic of infrastructure projects is to mobilize m**any stakeholders** of **very different sizes.** The tool should therefore be opened up to them gradually and without asking for investments they could not bear.

The smallest projects

The smallest projects are obviously the most numerous. The following table summarizes their major features.

Characteristic	Details
Size	They relate either to smaller structures, or improvements to structures in service.
Cost	These projects, which can cost from several million to tens of millions of euros, are obviously the most numerous and probably represent 80-90% of total investments (several tens of billions of euros per year in France).
Complexity	Their complexity is nevertheless often large, especially for structures in service.
Stakeholders	Stakeholders in these markets are actually quite numerous and vary in size, but are often small (SME).

Slower, but inevitable, penetration of the IM

The size of each project **is not,** in principle, **sufficient to justify** the necessary investments to implement an IM.

However, when the tools and methods have been developed for **large projects, t**here is no doubt they will be used for virtually all of these projects.

The profession will have to:

- **disseminate methods**;
- **train users**;
- **make the IM tool accessible to** all at a cost in line with the savings on each project.

Summary

All futures markets concerned

All infrastructure markets are therefore concerned with the development of the IM. We must have this goal in mind to design tools and lead change.

Gradual penetration

It is likely that the distribution of IM will go through steps to limit the risks taken:

- Start with **limited parts** of a large project with the involvement of major project stakeholders (client, main engineering firm, main builder).
- Extend it to the whole of a large project with the involvement of the same **major stakeholders**.
- Extend it **to all stakeholders** in a large project.
- Use the IM on **increasingly modest** projects.

Slow, but urgent change

This change has in some ways already begun with the change-over of software to 3D and the development of D&B, PPP and concessions.

The **use** of a shared IM on an entire major infrastructure project could be a reality in **the next 5 years.**

The progressive **dissemination** of the IM into most projects should come about in the **next decade.**

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B - Features

Introduction

Relevant features

Consistent with the presentation of the functions of the collaborative environment described in deliverable L2-A, we now specify the features that underlie the global model.

These features all have the objective of coordinating and sharing project information. Regardless of their assignment to particular software, we'll start by listing them and describing them.

Six groups of features of the global model

We have grouped the features around six objectives of the global model:

- model,
- exchange,
- calculate and simulate,
- manage,
- view,
- optimize.

These six goals structure the remainder of this chapter.

An inventory to be distributed in an architectural schema

The architectural schema of features that leads to the architecture of the software packages will be presented in Chapters C and D. Also, the features of the six goals outlined above will be cross-referenced with these schemas.

B1 – Modeling

3D authoring software

The action of authoring (or modeling) is performed using **3D authoring software** (or **a** 3D modeler), known as an "*authoring tool*" .

Purpose and use

This is a computer application used to **create 3D representations c**omposed of complex shapes or 3D objects, from basic primitives or analytical definition.

3D authoring software is used:

- In computer-assisted **industrial design**.
- By **graphic** designers who draw scenes to create animations, presentations or virtual reality environments.

Handling of basic shapes

They are essentially based on the manipulation of basic shapes: cubes, spheres, cones, and even Bezier curves or NURBS[2] (Non-Uniform Rational Basis Splines). They generally offer a **toolkit** that can model these basic shapes to obtain more complex shapes.

Transformation

These authoring software packages can be simple geometric transformations. They can also perform more complex transformations, making it possible to **change** parts of the shape, **cut** them, or **twist** them in all directions.

They may operate on **other attributes** such as:

- the texture of the object,
- color,
- how it transforms the light
- the owner of the object,
- creation date,
- status in the various validation or approval flows.

Moreover, they describe l**inks** between different objects, for example:

- membership or dependence,
- contact or distance to be respected.

3D modeling: a gradual, iterative process

3D modeling is a gradual, iterative process. It **adapts to the level of development** of the current phase of study, from the first sketches based on simple geometric representations of volumes and outline dimensions (parallelepipeds), to the details of some of the most sophisticated manufactured accessories (safety barriers, street lamps, etc.).

Authoring software is an application with a **high human added value**, although it is assisted by computer. With such software, the designer brings to the project all his knowledge, reasoning, imagination and knowledge.

[2] *NURBS* : Mathematical representations of 3D geometry that can accurately describe any shape from a simple 2D line, circle, arc or curve to a surface or a 3D organic solid of very complex free form (http://www.fr.rhino3d.com/nurbs.htm).

Authoring software for infrastructure projects

The 3D software must include the **basic** modeling **functions**:

- creation of **axes**,
- representation and manipulation of **natural terrain** (pegging out of points, contours, triangulation, etc.)
- advanced features necessary for **environmental management** essential to the project,
- representation of **geological strata** (by extrapolation of known points), since a project is rarely "above" the terrain.

As part of the design of infrastructure projects, some phases of creation are expressed only in 2D (in particular for some plan views of complex curves, such as spirals). We must therefore maintain a **strong interaction** between a 3D object and its 2D representations (plan views, elevations and cross-sections).

Real time visualization in design of objects

The modeling of complex projects is imposes a large dependency of:

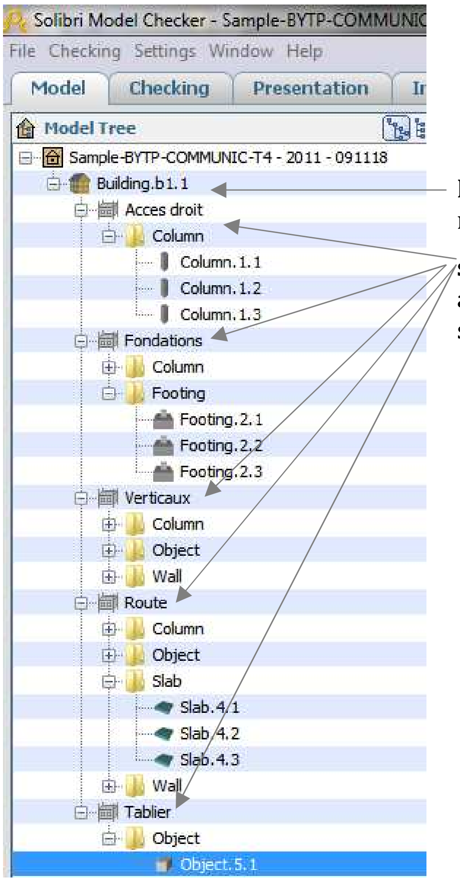
- **objects with one another**,
- **views with one another**.

The **links** and **dynamic relationships** between the objects and views of the work must be kept and updated in real time.

This makes it possible to work on **several axes simultaneously, a**nd immediately measure the **impact** of the design or optimization on the entire project or sub-project under study.

Objects to standardize

Working in "object" mode means manipulating the **elementary components** essential for all infrastructure projects.



Level 1 object:
reference building b.1.1

s Level 2 objects, of different types: access ways, foundations, vertical structures, road, deck.

Figure B1-1: Structuring into objects

Examples of discipline-specific objects

Here are some examples of discipline-specific objects. Their exact definition could be the subject of another research project. Indeed, there is now **no complete standard** describing these specific objects, except for the part concerned with bridges described in the IFC-Bridge standard.

To define	Specific objects
Engineering structure (over- and underpasses tunnel, cut & cover, roundabout)	Pile Deck Segment (and the need for sections perpendicular to the slope of the axis)
Earthworks	Cutting / Embankment Drainage
Platforms	Subgrades Pavements
Sanitation	Basins Hydraulic Structures Natural watershed
Buildings	Toll plaza Service Center Rest Areas Refuge

Catalogs of standard objects can also be prepared by equipment suppliers in order to allow direct insertion.

These families of objects must be validated or supplemented to satisfy the modeling protocol selected.

Other functions to model

Beyond modeling the geometry of the project, other functions must be integrated into the 3D authoring software:

Function	Features
Represent the **phasing of** construction	**Animated representation** of the entire construction project, with the sequencing of the various construction sites and major phases of construction. **Successive representations** of the same structure over time. Representations of temporary diversions and bypasses.
Represent objects with the level of **development** imposed by the design phase	**Several representations** of the same object. Opportunity to **select a level of development** for all objects based on the design phase in progress.
Use **parametric objects**	Some variable values may allow **adjustment of the object** to the context.

Software performance

It is important to focus on software performance, especially the ability to manage complex, long projects, which requires:

- **Decomposition / breakdown of** the project, with inter-dependence between parts. This isolates a section so as not to have to handle the entire project.
- **Effective management of** references. This allows work on a specific discipline of the project with reference to the environment that constrains it.

Parent / child links

Finally, in parallel with the geometric modeling capabilities, it is important to establish links between objects:

- **Parent link**, which connects the object to dependent sub-objects (the object is the parent of such objects).
- **Child link**, which connects the object to other objects that use it (the object is the child of such objects).

These links enable us to **know the impact** of a modification on the objects which interface with it.

B2 - Exchange

Export and import...

Data must be exchanged with different tools.

For this, there is a need to create the ability to export and import:

- **data** created by the modeler to the collaborative platform
- **results** of calculators and simulation tools,
- **documentation** (such as 2D drawings).
- **information** stored in the collaborative platform to various business tools.

... using the exchange platform

This feature is strongly linked to **the exchange platform.** This is the crucial issue in collaboration, and ensures that each item of data (attributes or links) is in a **neutral format** and has an **enduring structure.**

B3 - Calculate and simulate

Using the data

Once the geometry has been defined, other software packages can use the geometrical data to perform calculations and simulations. These software packages are called "**Simulation tools**"("*Expert tools* ").

Let's make a non-exhaustive list showing the diversity of the simulations.

Simulate earth movements

This type of simulation is strongly linked to **geometric modeling.**

It is therefore advisable to fully integrate an authoring software package (which creates objects) for data entry and the viewing of results.

Human expertise is of **prime importance** because automatic simulations seem impossible. This is due to the many parameters which have to be entered, adjustments to make, and iterations to converge to an optimal solution.

Provide several types of simulations

In addition, depending on the design phase in progress, it is interesting to provide several types of simulations. This **smoothes assumptions** before launching into detailed and extensive calculations. A first rough result allows selecting movements of large masses before **starting long, refined iterations** in the detailed design phase.

Other simulation software packages

Here is a list of other types of simulation software:

Type of simulation software	Goal: simulate / verify
Traffic	Traffic forecasts
Acoustic study	Forecast of noise during the construction period, or during operation
Hydraulic	Different flows (drainage, sanitation, ditches, gutters, etc.).
Visibility	Visibility in curves and roundabouts
Lighting	Lighting in urban areas, at interchanges, in rest or parking areas, etc.
Gyration	Accessibility of certain vehicles on portions of winding roads, etc.
Evacuation	Aspects of accessibility or evacuation of people in tunnels, etc.
Aerodynamics / Ventilation	Air flows in tunnels, or wind on structures exposed to strong winds

Highly iterative simulations

Other simulations that require strong interaction with the software:

- **Clash detection**: based on conflicts, geometric or not .
- **Planning (4D)**: based on a strong interaction between geometric objects and tasks on a bar schedule.
- **Quantity take-offs and quantities**: carry out price studies, naming of materials, estimates of "carbon footprint", optimization of material quantities or of recycling potential.
- **Construction phases**: simulate achievement sequences in space and time.

Manage iterative simulations

All simulations are repeated to **refine and optimize** the design.

The result of the simulation should be **graphical if possible**. But it is especially the **analysis** which follows from these results that is most important. We must retain:

- information about the **computer code** used (name, version, etc.)
- **assumptions** made by the simulation;
- **geometry** taken into account (often pre-entered in the software), taking account of the version of the objects used or the date of data recovery;
- **related attributes** (entered in the software or the simulation tool), taking account also of the version of the objects used or the date of data recovery;
- **final results** (possibly, representative intermediate results);
- **analysis** of these results.

It is not necessary to save the computer code alone, the intermediate results (not always relevant) or the methodology.

Link the geometric model with analytical models

The use of these simulation tools requires **structuring of data,** and especially use of a **neutral exchange format** between modeling and simulation software.

The data model used by the simulation tool is called an **analytical model**. The data may be filtered, degraded or adapted to the simulation tool.

Transform data

It is therefore necessary to transform the geometric and attribute data of the simulation tool, in order to extract **only** the information **required** for the simulation tool (concept of *Model View Definition*).

Maintain one-to-one links

Moreover, it seems of prime importance to maintain one-to-one links between the geometric model and the analytical model.

All these dynamic links are subject to the **approval** and d**ecision** of the engineer in charge of the simulation, or the designer responsible for the geometric design.

Change requests are essential to obtain acceptance of the inclusion of proposed amendments.

Pre-processor / post-processor

The enrichment of the geometric data with the discipline-specific attributes necessary to the simulation can be performed directly in the **authoring software** or in a graphical interface used as a **preprocessor** to the simulation tool.

Listings are less and less effective

The use of listings of data (entry of information in text form) is less and less effective. This is due to:

- the **complexity** of projects (number of important nodes, and considerable mental representation work);
- the current power of viewers and graphical user interfaces;
- **the ease of using** graphical data from simulation tools. They are accessible in a special viewer (post-processor to the simulation tool), or directly in an authoring software package.

B4 - Manage

A rigorously administered IM

Using a common shared database requires a specific collaborative tool. This is a **software management and concentration platform,** which serves as a "*collaboration hub*" for all data, information and applications for the project.

This collaborative platform requires high-performance administration functions to ensure confidentiality, accountability and trust among all partners involved.

Execution

This administration may be granted to:

- **One member of the project**. However, attention should be paid to the rights of the super-administrator who can access all the information in the database.
- **A trusted third party,** neutral and without responsibility vis-à-vis the project by himself.

Note: Some collaborative platforms can "repudiate" the super-administrator when the hierarchical structure of the common base is created. He can no longer access certain information controlled by sub-projects of the overall project.

Quality of imports and exports

Compliance with exchange protocols is critical to ensuring data quality, both in imports into the "*collaboration hub*" (from authoring software packages), and in exports (to authoring and simulation software packages).

It is therefore essential to ensure **proper certification** of authoring software vis-à-vis exchange formats by submitting sets of **test** data for automated verification (eg "*BuildingSMART International online platform certification*' on http://www.buildingsmart.com/content/certification).

Build trust by protecting private data

Perfect control of this administration and **knowledge** of its operation by all members is of prime importance to ensuring trust between partners. Therefore, private data is distinguished from public data.

Private data

Private data is data under development that should never be shared with other partners.

It is obvious that confidential data should not be found in the joint collaborative database. It must be kept in a **receptacle or container specific to** its owner, as long as it not yet complete or does not conform to requirements.

Permanent storage of the IM

Physical storage (support computers) of the principal database must also be considered from the beginning of the project.

Principal contractor

The database falls under the province and is the responsibility of the owner of all the data: the principal contractor.

The operator of the structure or project

However, we must take account of the **use of the data** at the end of the project lifecycle. It is the operator of the facility or project, the partner who uses the data, who is best able to maintain, operate and update it.

Moreover, he **ensures the perenniality** of the data, that is to say its accessibility for some decades. He therefore regularly updates the **format** of backup data to ensure availability of the data for the duration of operation of the facility.

A main model, and synchronized secondary models

Besides the main database, we must also ensure the mechanisms of **synchronization** and **duplication** with secondary databases hosted by different partners.

The extended company principle proposes having an exploded data **architecture**. This is an architecture with multiple servers scattered within major corporate users, for reasons of performance, responsiveness and reliability of computer connections.

The duplication of data between servers is:

- synchronous or asynchronous
- always automatic and transparent to users.

B5 - View

A viewing tool complementary to discipline-specific viewers

All display functions are accessible within the authoring software and simulation tools. Nowadays, all tools are equipped with **specialized graphic** viewing resources. They help users understand diagrams of results in a specific discipline, without interfering with other accessible information.

But it is essential to provide **independent viewers w**ith an intuitive user interface so that even stakeholders who are not experts in the handling of discipline-specific software can understand and run through the project and the simulation results.

Installation and deployment

Here are the installation and deployment requirements for a viewing software package:

- **compact** for easy downloading;
- **easy to install -** no special administration fee and no tedious entry of coordinates on an Internet server;
- **compatible** with standard operating systems (Windows XP, Vista, 7 and beyond) in 32 and 64-bit versions;
- **easy to update** by automatic downloading via the Internet;
- **free of charge** to be widely distributed among stakeholders and partners.

Need for performance

A major concern is the **performance** of the software vis-à-vis large models (thousands or millions of objects). This is because this software is often used after aggregation and integration of data from many disciplines to ensure consistency and compatibility of information between them.

Views suited to each stakeholder

Each stakeholder group has its own requirements for the ideal 3D viewer, depending on the discipline.

Common specifications

Several specifications are common (basic features). They relate in particular to reviews, analysis, and the editing of 3D models:

Aspects to consider	Expected views
Societal	For communication: precise data, rendering as realistic as possible.
Environmental (pollution related to construction noise and vibration)	More specific but less realistic.
Impact on existing traffic	Overview with no need for detail.

Advanced features

In addition, some only need to **check** a model, while others must make **changes** and still others **view** simulation results.

These advanced features should be considered *Plug-ins*[3]. These are additions, specific to a discipline, which cannot operate independently of the basic functions.

[3] In computing, a ***plug-in*** is software that complements host software to give it new features

Escalation and viewing possibilities

Viewing performance also has to do with the passage from an o**verview** (macro vision, lack of detail) to a **detailed view** (micro vision, with a maximum of fine details).

The viewing tool must adapt to the demand, such as a view of progress:

- of the **project,** displaying the progress of execution after specifying a particular day;
- of the **design,** displaying the progress of the design with a color code corresponding to validated objects, uncertainties, collisions, etc.

Basic functions

The basic viewing functions handle the most important needs:

Basic functions	Features
Handling data and files	Import of file formats (dwg, dgn, rvt, etc.). Partial export of data (by selection of zones or use of filters) Multi-file view (aggregation of multiple files or opening of files in separate windows)
Viewing data and their attributes	General display functions (zoom, panning, orbiting a pivot, etc.). Transparency features, or disappearance / appearance Wire or surface rendering features
Navigation through 3D model	Different navigation modes (flight, rotating around a pivot point, exploration of a model, etc.) Viewpoints (save and display)
Measurement	Distance Angle Length Surface Volume

The measurement function is **complementary to attributes** which sometimes give accurate distances or dimensional features of objects.

Desirable advanced features

Desirable advanced features are described below, without being exhaustive:

Advanced features	Characteristics
Tools	Creating annotations (saved in a separate file) Hypertext links Selecting objects
Navigation within objects	Display of properties (version, creation date, attributes, links, etc.). Object tree (structural breakdown)
General functions	Printing Search Quantity

B6 - Optimize

Optimizing means combining basic functions

Optimization is a complex process. It must be based on quantifiable performance indicators to compare the design to the needs expressed.

Optimization is the combination of all of the functions described above. To optimize a project, different stakeholders need to:

- **enter** data and parameters,
- **view and understand** all the information,
- **recover** data created by all the other disciplines,
- **make** iterative **simulations,**
- **take decisions** according to the results obtained,
- **change** certain parameters to restart an optimization cycle or a design alternative.

Parametric objects are paramount

For this, parametric objects are of paramount importance. This is because parameters make it possible **to adapt the dimensions** of objects to their context or their environment simply by changing some properly identified named values. This conclusion is completely accepted in industrial 3D modeling, for example.

The IM simplifies the work of the expert ...

Optimization is the responsibility of an **expert**. He needs to sort the data, screen them according to criteria of relevance or interest, and select the areas and elements to consider.

The numerical results of the discipline-specific tools are **fed into the IM s**o that they can be consulted and synthesized. The e**xperts** then make their choice, refine the study and take final decisions. The management tools of the IM must offer these features to simplify the work of experts.

... but it is always the expert who does the optimization

In any case, the optimization of a project or study must not be based solely on the tools. The tools used must not be "black boxes" that provide a final solution. Optimization must remain a **rational human choice b**ased on the expertise and experience of the decision maker and his team.

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C - Architecture

Outline of Chapter C

After listing the major features of the environment of the IM, we describe in this chapter how they are organized into the **global architectural** schemas of:

- functions
- software tools that enable them to perform these functions.

We then describe how the **functions** are distributed in the software.

Note : The actual description of the tools is in Section D.

C1-Global architecture

Inventory of functions

The schema below shows the basic functions with:

- in the left column, the **functions u**sed by stakeholders,
- in the two right columns, functions concerning **information stored** in the IM,

in the middle column, the types of information exchange.

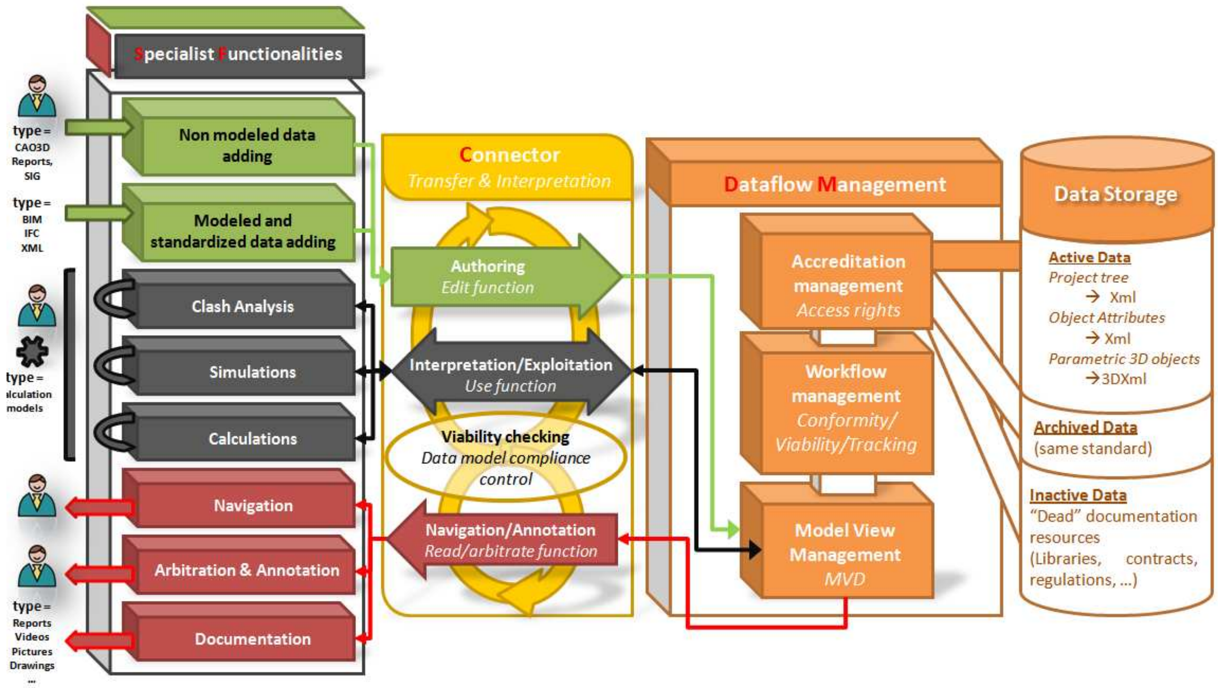

Figure C1-1: Classification of functions

Simplified global architectural schema

We describe below how we have organized these functions.

An environment consisting of large areas

The following schema shows the simplified architecture of the Collaborative IM Environment (EIMC).

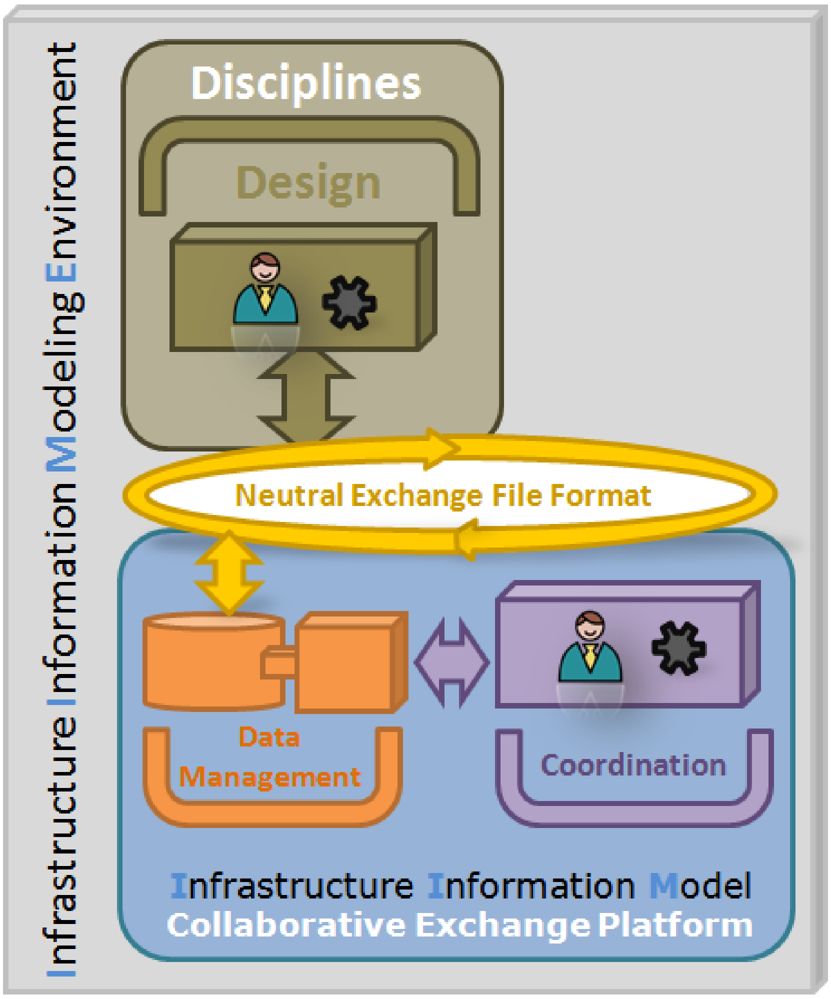

Figure C1-2: Perimeter of the global model

Perimeters

These schemas are constructed on the definition of **organized perimeters**:

- "**Environment of the** COMMUNIC **IM"** (EIMC)**:** perimeter of the overall model.
- "Disciplines": Designs of different disciplines.
- The "**IM**" or "**Collaborative Exchange Platform** (CEP): center of the model with two sub-schemes:
  - "Management" to manage information,
  - "Synthesis" to globalize the analysis and manage the project,
- **"Exchange platform" w**hich provides communication between the perimeters of the IM and the disciplines.

This structure will be described in more detail in Chapter C.

Representation charter

In all the diagrams in this chapter, we use the representation charter described below.

Perimeter		
	Disciplines	Tools needed to design a project.
	Exchange platform	Functions concerning the transfer of data, control, validity and consistency.
	CEP or IM	Perimeter of the collaborative exchange platform , also known as the IM.
	Management of CEP	Tools forming the heart of management of the IM: Collaborative Exchange Platform.
	Summary of CEP	Tools needed for technical management of the project (synthesis, arbitration, etc.).

Types of features		
	Authoring and direct inputs	Features forming part of the process of data integration in the IM, hosted by the CEP.
	Computation and simulation	Analysis and computational tools that take data from the central database for use by simulations and calculations controlled and operated by an expert who uses his expertise in this area.
	Editing and visualization	Features and processes for using data in technical documentation and publishing: export of such data in a format that does not allow their return, following a change, without remodeling (e.g., annotation of exported plans).

Pictograms		
	Human intervention	Fundamental human intervention in the value creation process .
	Engineering work	Engineering work specific to one or more disciplines.

Detailed global architectural schema

Major functions of the "disciplines" and "CEP" perimeters

The two "disciplines" and "CEP" perimeters cover basic features that can be summarized in the architectural schema of functions below.

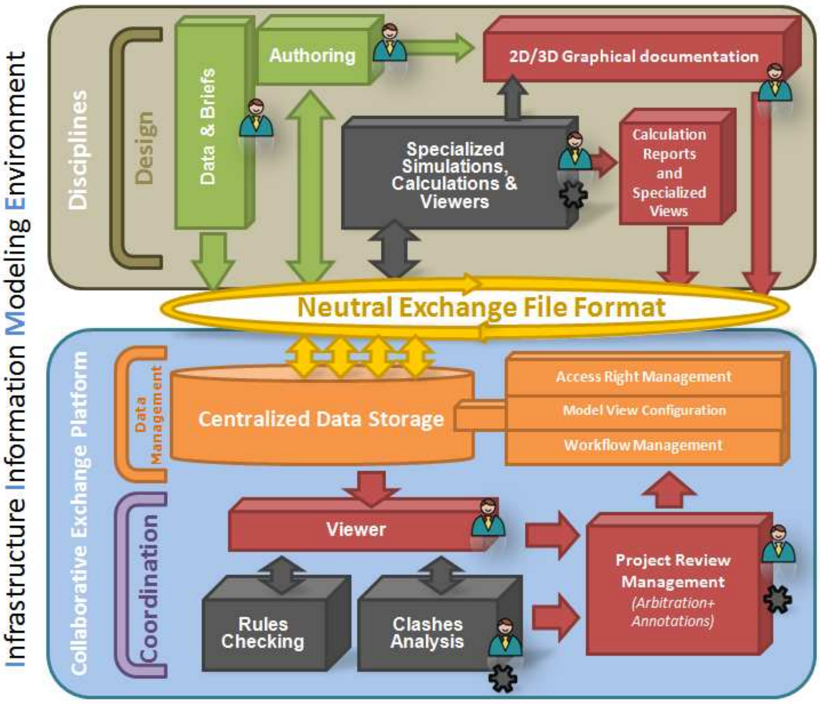

Figure C1-3: Detailed diagram of the features of EIMC[4]

Translation into a global software architectural schema

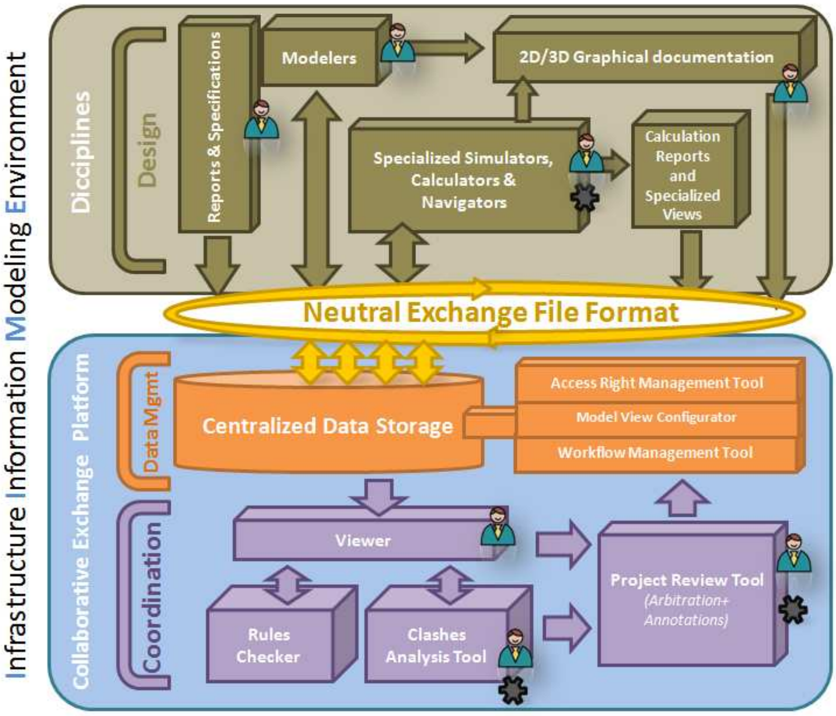

Figure C1-4: Detailed software architecture schema of the EIMC

[4] This schema is based largely on the work and conclusions of the INPRO European research project.

Operating cycle of software components

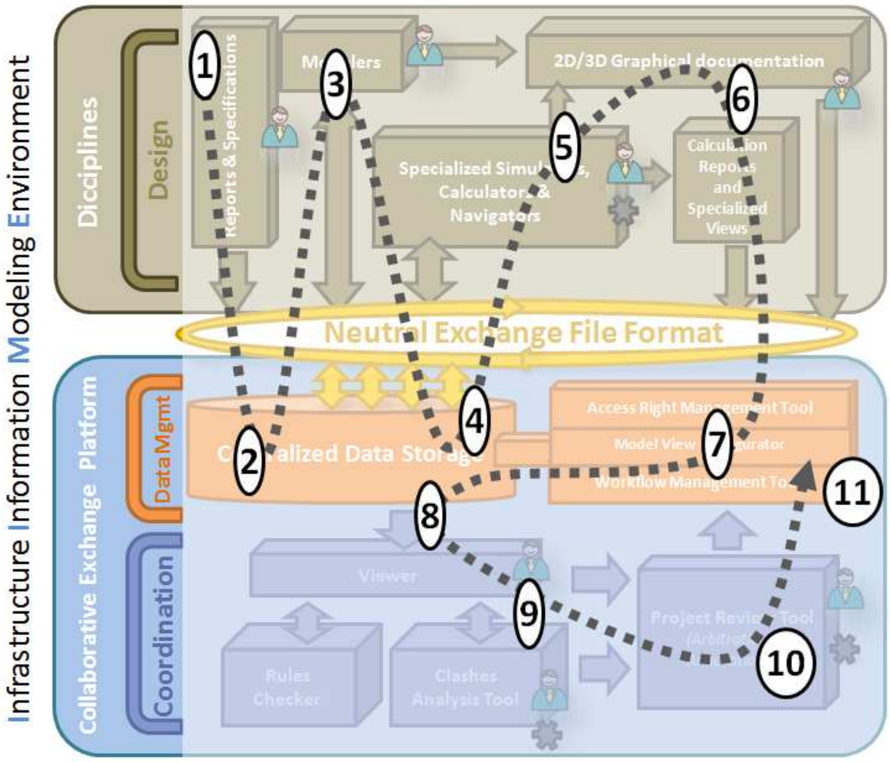

Figure C1-5: Operating cycle of software components

Comments on the cycle

In this example, the lifecycle of project data between different software packages follows these steps:

Step	Action
1	Customer specifications and deliverable data are ordered and classified n the project environment.
2	Data, catalogs and modeling charter (default model) hosted by the IM, are extracted.
3	A geometric response to needs expressed by the client is modeled.
4	This model is housed in the platform.
5	The design is complemented by tests, calculations or simulations.
6	The results of simulations and calculations are documented.
7	Everything is hosted and managed in the IM.
8	Navigation in the IM allows the proposals to be visualized.
9	Tests of consistency, integration and synthesis are performed and analyzed.
10	Design choices may give rise to arbitration.
11	The chosen design is stored in the IM to be seen and used by other stakeholders.

C2 - Distribution of features

Distribution of features by perimeter

The table below, within each perimeter defined in the COMMUNIC IM Environment, gives the groups of functions defined in Section B.

			ARCHITECTURE / PERIMETERS				
			Trades	Platform		CEP	
			Design	Neutral format	Compliance check	Data Management	Synthesis
FEATURES	Model		**X**	x			
	Exchange			**X**	**X**		
	Calculate and simulate		**X**	x			
	Manage	Manage		x		**X**	
		Store, Host				**X**	
	View		**X**	x	x	x	**X**
	Optimize		**X**	x			**X**

X: main function
x: important secondary function

Comments

This table shows features across multiple perimeters.

It is the **discipline-specific tools** that must adapt so that their information to be exchanged is in a neutral format. The **platform** should therefore *ultimately* have only the task of monitoring compliance.

Distribution of functions by type of software

The more precise table on the next page deals with:

- features reflecting the major objectives,
- software tools for each perimeter.

The precise *mapping* (correspondence) schema between functions and tools would be impossible to present here. That is why we have included only **major functions**.

For example, the viewing function is common to CAD, calculation and clash analysis as a simple navigation tool . But, it does not have exactly the same definition as it must adapt to the discipline in question.

Distribution of functions by type of software (Continued)

	Architecture	Discipline					Platform				CEP							
	TOOLS	Allotment of specifications / modeling of raw data	Modelers	Simulation tools, computers, discipline-specific	Graphic documentation editor	Calculation and discipline-specific view editor	Use of a neutral exchange format	Monitoring of data exchange compliance	Monitoring the completeness of data exchange	Monitoring of compliance in the neutral data model	Hosting of ordered data	Permissions management tool	Viewpoint management tool	Workflow tool	Browser	Rule checker	Clash analyzer	Arbitration and annotation management tool
Functions	**Features**																	
Shape	Addition of raw data	**X**					x											
	Manual modeling		**X**				x											
	Addition of modeled data	**X**		**X**			x											
Exchange	Platform for import of data to share						**X**	**X**	**X**	**X**		x	x	x				
	Platform for partial import / export of the shared data (interpretation)						**X**	**X**	**X**	**X**		x	x	x				
	Read / publishing export platform						**X**	**X**	**X**	**X**		x	x	x				
Calculate and simulate	Simulation			**X**	x	x	x											
	Calculation			**X**	x	x	x											
	Analysis of clashes						x									**X**	**X**	
Manage	Rights by identity						x					**X**						
	Flow monitoring (*Workflows*)						x							**X**				
	Viewpoint rights (discipline)						x						**X**					
Store	Host										**X**							
	Order										**X**							
View	Browse	x	x	**X**			x	x	x	x					**X**	x	x	x
	Annotate																	**X**
	Document				**X**	**X**												x
Optimize	Arbitrate						x											**X**

X: Main function
x: Important secondary function

C3 - Assessment of the architecture

Key points

When exchanges and their safety and quality constraints are globally taken into account, we realize that the key points of the COMMUNIC IM (EIMC) environment are:

- The **Collaborative Exchange Platform (ECP).** This is the crossroads of all work on the project. It is the place for managing and securing data.
- The transfer platform associated with a shared **data model** and **neutral** exchange **format.** All data are imported or exported through this platform.

Comments on the perimeters

Conventional definition

The perimeters were defined conventionally for the COMMUNIC project. During implementation, they can be adapted.

For example, we established a **specific perimeter** for the platform rather than integrate it into the CEP. This is a choice we justify to **call attention** to the major functions it must perform to ensure the data model and neutral exchange format.

Similarly, **standardization** (data model and format) of information is a function of discipline-specific tools. This is so even though, for some time yet, standardizations can be realized by **specific modules** of the platform.

Duplicates allowed

Some tools will be present in several perimeters.

This is for example the case of browsers (*viewers*). Indeed, it is essential that the CEP have an **integrated browser** that allows the synthesis functions. But this does not preclude that some disciplines have their **own browsers** for their own design work.

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D - Software

Introduction

Expectations for each tool

The purpose of this chapter is to discuss the expectations for each software package.

By software package, we sometimes mean a group of software packages performing functions, or a type of software with a generic meaning (discipline-specific modeling tool, for example).

Summary of architectural schema

See figure C1-4.

Presentation by perimeter

We will discuss the tools for each perimeter:

- CEP management tools,
- CEP synthesis tools,
- Exchange platform,
- Discipline-specific tools.

D1 - CEP management tools

Database management system (DBMS)

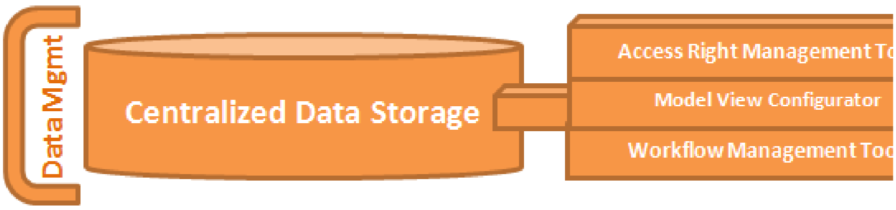

Figure D1-1 CEP Management tools

Key points

The Database Management System (DBMS) is a set of **Software packages** which **uses** a database. It can be acquired and implemented by the company itself or by a company offering this service.
Specifically, the database can be stored within the enterprise or in a data processing center.

The current DBMS ensures the following main functions:

- **Relations between the data.** The DBMS can be used to establish and manage relationships between data.
- **Data integrity**. The DBMS ensures reliability and consistency. This is a major feature of all DBMSs.
- **Data security**. The DBMS ensures data security, including checks of access rights.
- **Selective data viewing**. The finished DBMS allows each user to view only the data to which he has the right and which he needs.
- **Data sharing**. The DBMS provides an opportunity for multiple applications to share the same data.

Points to note

For the COMMUNIC project, the points which need attention have been identified.

Management of data

For us, data management means the management of:

- **versions,**
- **alternatives**,
- **validation status** of the information and associated circuitry,
- **properties -** private and public information, intellectual property, etc..

Currently, these functions can be found in Electronic Document Management (EDM) and *Product Lifecycle Management* (PLM) software. But these programs are designed to manage documents or files, not information carried by objects.

Sometimes we also find part of this functionality in authoring and project review software packages. For example, Revit integrates an alternative management function, and using the *Bentley* suite's *Dynamic Review* may grant a validation process to objects.

Unfortunately, the functions as they exist today are far from complete and perfect, particularly as regards data v**alidation** or **maturity**. Today's tools are most often **more or less optimized EDMs, w**here we should be using a project PLM.

Traceability

This maintains a h**istory** of how the data is handled. It fosters **trust** between partners and helps to keep track of the decisions taken.

This feature also appears in EDMs and PLMs for a database file. It must be transposed to the information attached to objects.

Management of "viewpoints"

The concept of "viewpoints" comes from the requirement to filter information to highlight that which relates to each stakeholder and not be drowned out by all the others. The DBMS must therefore manage the viewpoints of each stakeholder.

Currently, there is no concept of managing "viewpoints". In practice, it is handled by each software package, which takes all the data and converts those that can be used.

Management of data - access rights

Management of accreditations is traditional data security function.

The **IM Manager** (Or *BIM Manager*) defines the portions of projects which each user can access based on his guardian entity (responsible legal entity: design department, company, inspector, client, client's representative, principal contractor, operator, etc.). Moreover, **each responsible legal entity** is entitled to request a **finer segmentation** of access rights for its employees. So for most users, the project is only partially accessible.

In addition we also define the level of accessibility through the following 5 statuses:

Profile	User Profiles	Access
Visitor	**General public.** Accesses the model via the Internet or information terminal on site, or in an exhibition.	**Lowest access** in terms of rights. A user can see only the project in the **state which is most validated** by the project community. In addition, he has access only to level 3: from the geometry to the level of discipline-specific detail.
Reader	**Partners** of the association type. They can access information, but must use review meetings to communicate their suggestions and opinions.	This is the **first access right** in the project community. If no other restriction has been issued, it simply means having **access** *to* **all development levels** and attributes without being able to change them, or even making an arbitration or endorsement. This is a p**ure consultation** of the central model. However, graphic export functions are available through this access.
Reviewer	**Project manager** in a partner entity.	Provides his opinion, consults a clash analysis which affects his entity.
	Project community partners in a review meeting	Arbitrate technical decisions, clashes, and annotate any part of the project.
User	The most common profile	Adds data, uses it for an expert appraisal (calculation, simulation), modifies it manually or via an online expert tool, or exports a viewpoint or report. Access to all expertise functions, unless there are additional restrictions: alphanumeric data entry / import, calculation / simulation / analysis and export (related documents, reports and tables), and charts (curves, views, videos).
Group administrator	Persons in charge of IM partner or management entities for all partners	Administer a particular user group. Restrict access rights to the central system for organizational and management reasons internal to a partner entity. More specifically, manage access to the central user system for which he is responsible. Note: This profile also covers all the rights available to the user, reviewer and reader profiles combined.

System administrator

This engineer works with the manager of the IM to:

- Manage the central system.
- Create, modify and delete access rights, and define roles for the MVD (see next section).

He does not have access to the data.

Workflow management

Go from workflows of documents managed by the EDM ....

The *Workflows* are used to qualify:

- the authenticity of the data,
- the level of relevance of the data.

Today, EDMs can both allow shared archiving of documents and associate "*Workflow"* information with the documents .

These systems are structured around an RDBMS that provides a link between a document and the features that in particular allow:

- **identification** of the document,
- the **position** in its life cycle (versioning)
- the **status** (validation),
- other documents as **references**,
- s**imultaneous** use by several stakeholders.

... to information workflows managed by the digital model

These features are all integrated into the Collaborative Exchange Platform (IM), with two new aspects taken into account:

- The *worfklow* is no longer attached to a document (a drawing, report, file), but to **information** bound to the constructive object. In other words, information management tools must be **integrated with the data model** of the IM, which makes the attribute, associated with the object, the basic management unit.
- The conceptual model of the *Workflow* must itself take into account the **complexity** of the information validation cycle , including **links with** other information.

Management of "viewpoints"

Navigating the IM according to criteria

The management of viewpoints is **synonymous with "*Model View Definition*"**. It makes full use of the data model, profile management and *Workflow* we have described above.

This provides each user with a range of criteria for navigating the IM, and making **requests** which are relevant to him. These criteria are listed below.

Depending on the nature of stakeholders

A first criterion is related to the profile of the stakeholder and his access rights.

For example, the public does not need to see the **constructive details** of a reinforcement if it is the insertion of the structure into agricultural structures that concerns them.

According to discipline

A second criterion is the discipline of the direct stakeholder.

For example, a stakeholder in the earthmoving business will wish to have all details of earthworks, and therefore see all **child objects** of the earthmoving object at Level 2. In contrast, children of objects in other disciplines at Level 2 do not interest him. It will be useful to be able to filter them out.

According to the lifecycle or its progress

A third criterion is of interest only to information relating to a phase of the lifecycle.

This is for example the case of a general presentation of the project while in the execution phase. It is also the case of selection of information according to its validation level or progress: What is approved information? What objects are being worked on today? etc.

By managing the characteristics of the information

Hence, for this purpose, the tool should allow **management of information** depending on its individual characteristics.

The case of export of "non-object" data

These are **graphic and alphanumeric** export tools**:** maps, graphs, reports, calculations, lists, videos, etc.

Starting from the premise that all of the information is stored in the database, one case simply:

- retrieve the information necessary to prepare the report,
- format the report using a predefined template.

Today, there are software packages that can export "**reports** of *clashes*" and a **list** of all elements and their attributes in a table.

They are now an integral part of some simulation and calculation tools. They cannot be used to produce reports directly by transcribing a cross analysis between the weighted viewpoints of the various disciplines.

Tomorrow, automation and image export

It will soon be possible to automate the preparation of technical notes, calculation notes, schedules, deliverables, etc. This is already possible today with some tools, but tomorrow it will be possible from a **simple reading of** the neutral format.

Similarly, it will be possible to export images and videos from the central IM for communication.

It can also be envisaged that this functionality will be integrated with the collaborative platform to save, for example, a **graphic** charter common to the project, or to be able to **track what exports** were made by whom and in what state of validation and maturity.

D2 - CEP synthesis tools

Synthesis tools

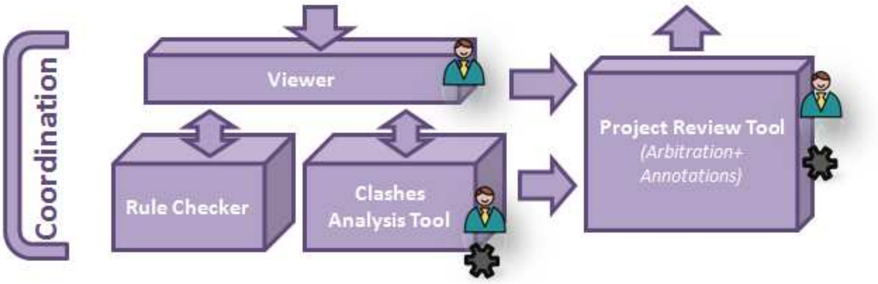

Figure D2-1: Tools of the CEP synthesis part

The universal browser

Based on the object data model defined by COMMUNIC, the browser is the tool that allows the IM to:

- **consult** stored data (3D geometry, attributes and links, trees);
- **view** objects at various levels by moving in the virtual structure in real time;
- **create a location-based link** between information and the objects that carry it .

The browser is the universal tool of the IM for accessing the data. In some cases, there may be dedicated browsers specific to particular issues.

Today ...

In the software packages currently available, we find many products with which to display certain data formats.

Many are distributed free of charge. For example:

- Revit Viewer (. rvt)
- Bentley View (. dgn)
- SOLIBRA Model Viewer (.ifc and .smc)
- Nemetschek IFC Viewer (.ifc)
- DDSViewer (. ifc).

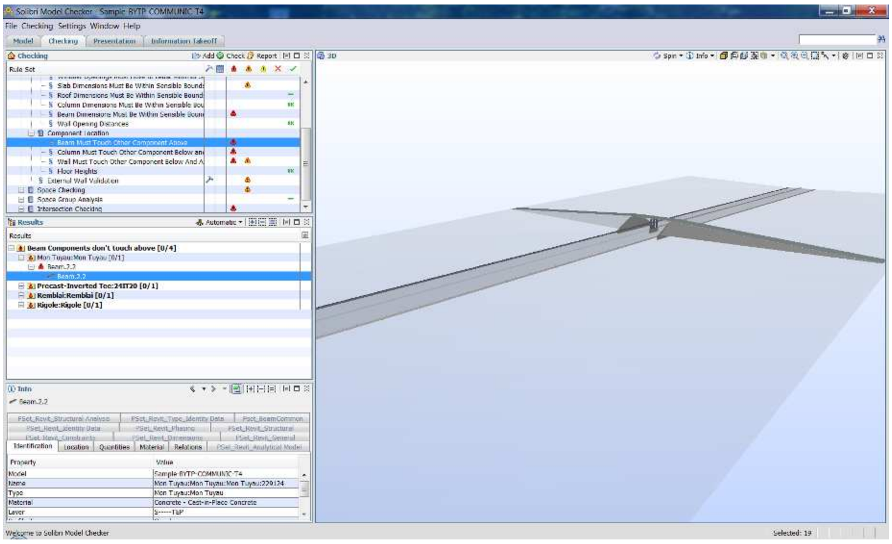

Figure D2-2: Model of earthmoving of the experimental area in the SOLIBRI viewer

... and tomorrow

In COMMUNIC, we propose to integrate a basic browser in the collaborative exchange platform. The browser will be able to provide the following functions:

Access rights

The browser uses the access rights management module , so the user has access only to data that he has the right to view and edit.

Visualization of discipline-specific analysis results

The specialized designs of the disciplines will result in **calculations**, **analyses**, s**imulations** and even **visualizations**.

When the designer decides to share the results with other stakeholders, he will place them in the IM. The browser will then display them. In particular, it will be possible to visualize them by **superposing** numerical results on the geometric model.

To illustrate this feature, we will take the case of acoustic studies with visualization of sound impact on objects of the IM.
Checking software can do the same kind of presentation for:

- structural analysis,
- climate analysis (heating, air conditioning, ventilation)
- 4D (3D + Schedule)
- 5D (4D + Cost)
- etc.

The figure below shows one possible display of sound impact on a project area.

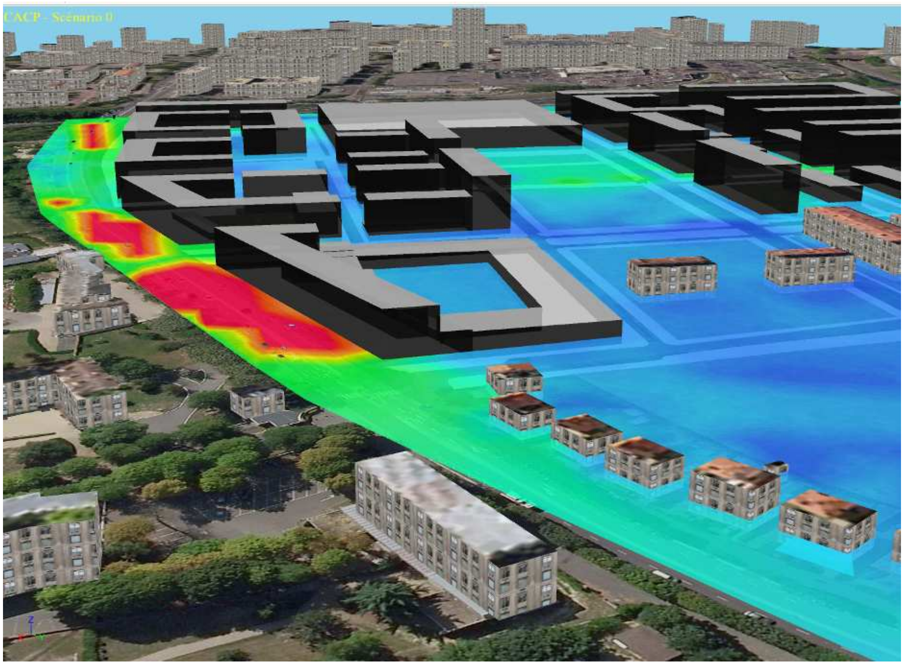

Figure D2-3: Result of an acoustic analysis

Tree according to the viewpoint of the user's discipline

This tree should be organized around the basic structure and hierarchy in different levels (related to increasing precision of design). The tree structure that we established in the COMMUNIC project during the experiment is shown by the partial view below.

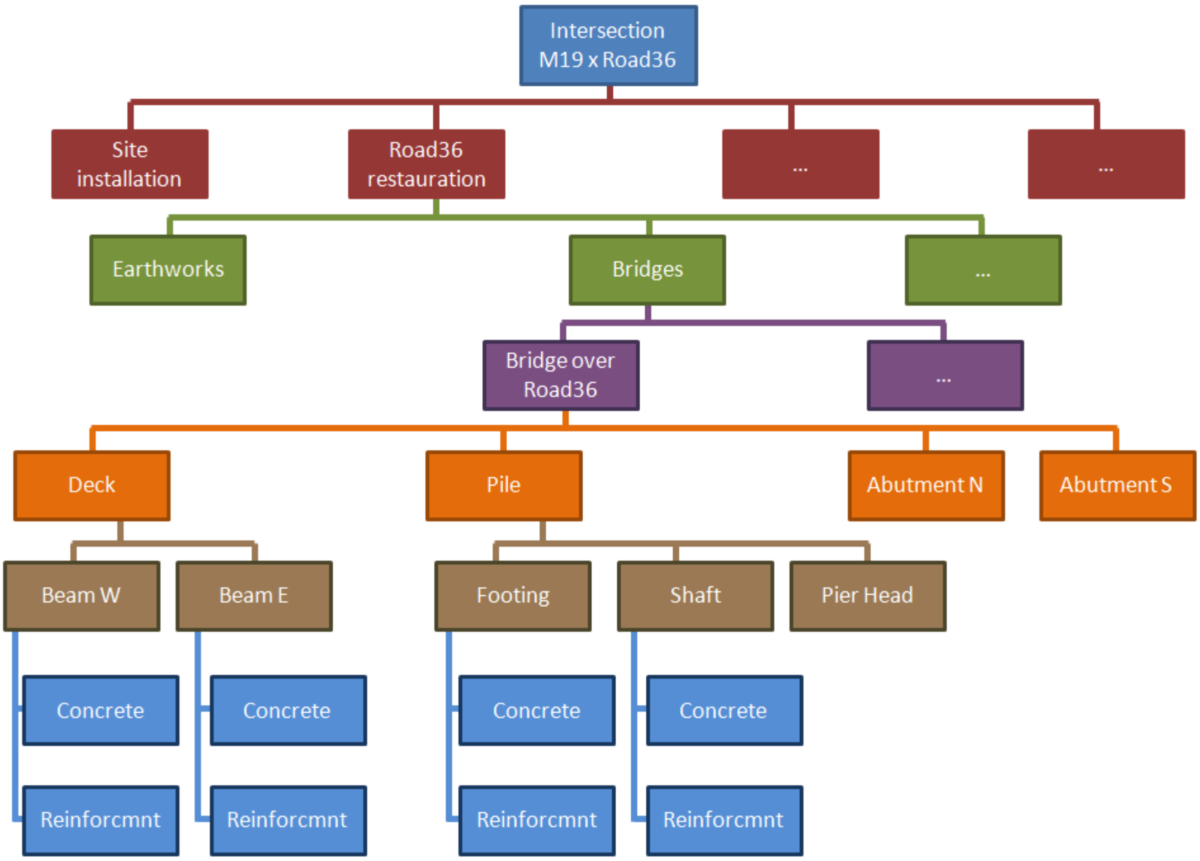

Figure D2-4: Extract from the tree developed for experimental Task 4 of the COMMUNIC project

Query by the browser

The query can **limit the data** to be visualized. The user is not buried in an excessively large mass of information, and quickly finds the information he needs.

The query criteria proposed by COMMUNIC are.

- **Geographical location**

Many cases require loading only **part of the p**roject, defined by geographical location. In the case of a complex project, it is likely that an engineer will be in charge of only one project area. For example, an earthworks engineer may be studying the first 10km of road. He may not be directly interested in the road beyond that.

- **Systems and disciplines**

A system is a set of objects in close relationship with each other, all performing well defined functions. In the COMMUNIC project, we d**istinguished the following systems**: drainage network, tolls, signing, monitoring, landscaping, operation and service, etc.

A discipline is a human activity in which experts in the discipline, working on a set of objects, use their **know-how** to achieve a **given objective**. The disciplines that we have chosen are the geometry of the project, earthworks, planning, cost, pavements, traffic flow, land, environment and archeology.

To facilitate the work of each user, the ability to **query** by systems and by disciplines seems essential for proper utilization and performance of the IM.

- **Links**

Links are an important part of the IM. And it is not often possible to view them in graphical interfaces. However, to understand the relations between objects, we must find a way to make them stand **out**.

- **General Attributes**

In addition to the specific querying mentioned above, the data browser must allow a query on any attribute. This **list** is not exhaustive, as other query criteria will appear when the IM is used.

Clash analysis tool

This tool is currently one of the few **present and operational** among the various software packages on the market. The current tools can effectively detect interference and collisions, more commonly known as "clashes."

There are 5 types of clashes.

Geometric

The geometry type is trivial. These are **geometric intersections** commonly called "clashes", which correspond to the intersection of two volumes or the accidental inclusion of one in another.

Functional

They:

- check **the absence of collisions** in kinematical studies of moving parts,
- control **the existence of the volumes** necessary for assembly or disassembly tools, or the volumes required to access narrow parts of structures or hard-to-reach parts.

Parametric

This concerns the **management of tolerances** between objects, such as the thickness of the cover concrete. By this means, it is possible to verify that no selected reinforcement is "too close to the surface of the concrete", to avoid errors leading to the well-known spalling damage.

Regulatory

This involves checking **compliance with design rules**, e.g., regulation of the design of outdoor public spaces, such as a rest area, primarily for access by disabled persons This regulation is primarily focused on strictly geometrical issues of the shape of stairs, slopes and minimum dimensions of spaces, etc.

Specific

This involves checking **compliance with design rules that are not regulatory**, but issued by the client or defined by the project community.

A rule checker for the last 3

The last 3 types of clashes are analyzed by the rule checking tool.

However, the information about the existence of clashes is not itself hosted in the IM. This allows it to be **directly accessible** through an authoring tool. These tools allow you to edit "clash reports" which can, in the technical development phases of certain projects, be as long as hundreds of pages. Indeed, the information output by these tools **is currently not "sorted", customized, managed or monitored.**

Rule checking tool

This is an extra layer on the clash analysis tool.

This involves **automatically** checking that the result is in accordance with regulations and with the client's performance requirements.

For example, if the model contains a rule on the maximum deflection of beams , the **rule checking** tool can continuously detect beams of which the sag exceeds l/250 (l being the length of the beam) for the SLS (serviceability limit state). Engineers are thus **notified in real-time** about the elements it is required to change.

Similarly, it is possible to verify the correct application of urban design rules or rules giving accessibility to persons with reduced mobility.

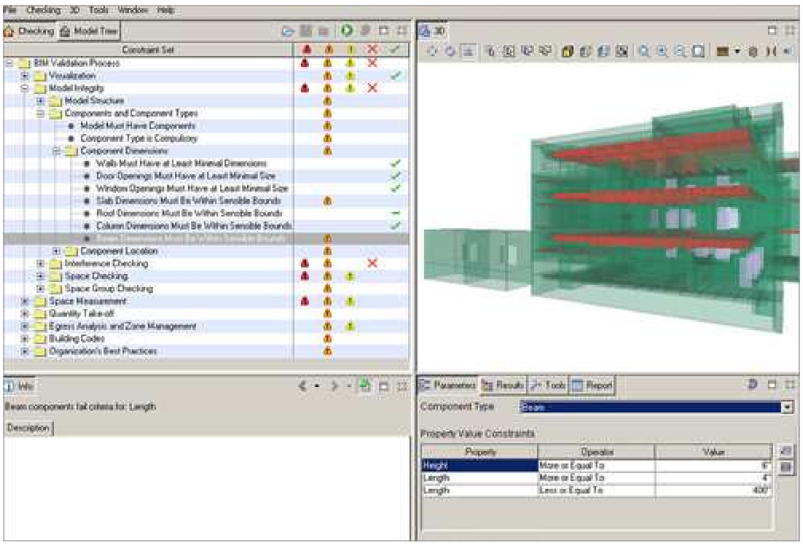

Figure D2-5: View of a tool (SOLIBRA ®) to verify compliance of design rules

Project review tool

Intervene in the information workflow

The a**rbitration** and **annotation** tool helps in :

- revising the project,
- decision making,
- external communication of the project team.

It can not add, delete or edit existing data (except the v**alidation** and r**evision** attributes).

Save the history

In the design phase, a **comparison of analyses** based on two alternatives of the same object (the results of various simulations, geometries, costs, etc.) will allow the making of informed decisions.

In the study phase, we must resolve conflicts, make decisions and validate solutions.

During the "***review gate***" at the end of each phase, a number of important decisions must be accepted by all partners. It is particularly in this phase that the use of a **specific browser** should make it possible to view and identify inconsistencies and record decisions and approvals. The IM thus keeps **track** of everything that was done and decided to arrive at the final version of the project.

Dematerialize the reviews

It is preferable to integrate the tool with the collaborative exchange platform to:

- Help **dematerialize project reviews .**
- Substantially **reduce travel** by stakeholders expected to participate in review meetings. This allows everyone to stay home to draw up these coordination reviews. They are more numerous and more frequent than in a traditional process.

D3 - Exchange Platform

The keystone of the global model

Transmit and translate

The **data interpreter** is a tool that transmits and "translates" data between the central IM and authoring and analysis, calculation and simulation software.

It is the **keystone** of the EIMC. It aims to achieve perfect **control data transfers** and ensure their **reliability**.

For input and output

This interpreter works on the input and output of any tool and is defined:

- by an **equivalence class** between two data models, enabling inter-exchange of the building blocks constituting the whole design (discipline-specific) or the whole of the IM;
- in so-called neutral **non-proprietary formats** in the construction field such as IFC .

Cross-over point for functions

The exchange platform feeds objects, attributes and links from the discipline-specific tools to the data model of the IM.

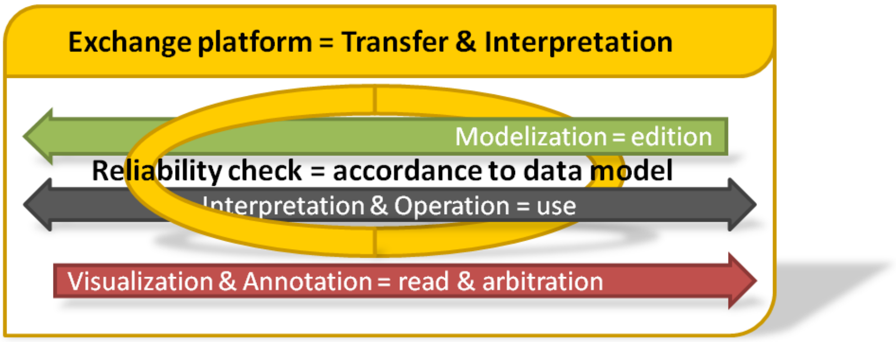

Figure D3-1: Functional composition of the transfer and interpretation platform macro function

Compliance monitoring

This feature has two aspects.

Compliance of input data with the model

This involves checking, and then accepting or refusing, the entry of data or a batch of data into the central model according to its location as proposed by the *Gateway&Transfer* system.

This is the last input check to verify that the **right information goes to the right place** according to the project object model chosen for the project (via a standard or standards selected for the project and its context). For example, data concerning the section of a steel reinforcement, addressed to a pavement layer by a **computer error**, would be refused.

By this means, it is also verified that a linked document does have the **nature** it claims to have "attributively speaking" in the database. In other words, it is verified that if a drawing has been linked to an object by an expert tool, it is **referenced as such** in the partial model entered, and not as a text document, for example. This feature has **veto power** over data entry in the central system.

Data processing consistency of input data

This involves checking that the partial model entered is **viable** from the data processing standpoint, meaning for example that:

- Link address attributes do not point:
  - to nowhere,
  - to the wrong object (GUID error for example);
- the model entered does not generate a circular attribute reference between objects (see figure C2-3 below).

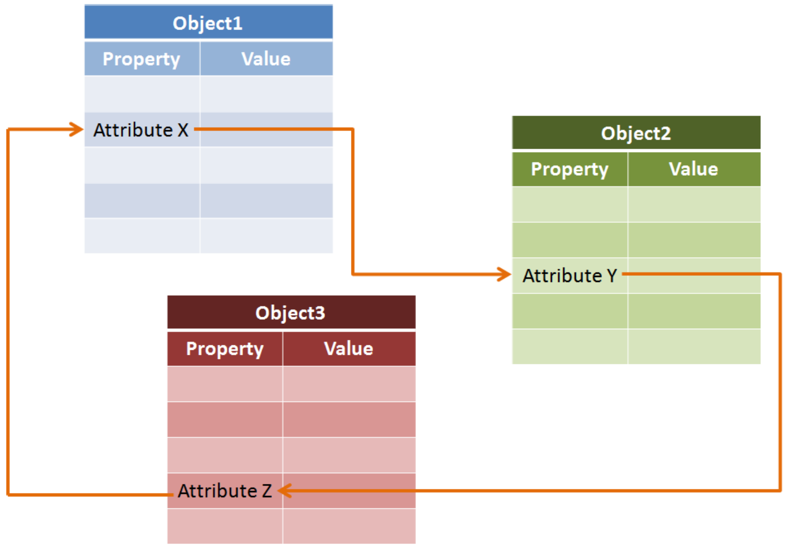

Figure D3-2: Circular reference of attributes

Guarantor of the independence of discipline-specific tools

Independence

The data-processing platform forms a bridge between discipline-specific tools and IM tools because:

- The proprietary data model must be translated into **a data model compatible with the IM**. The discipline-specific tool must ensure the integrity and completeness of the information.
- The IM must proceed in reverse: **restore** information generated ion or transiting the IM to the discipline-specific tools.
- The IM must be i**ndependent of discipline-specific tools**. At any moment it must be possible to **interchange** a discipline-specific tool for another without changing the model of the IM.

Transparency for users

Concretely, this tool is **"**transparent "for users.

A user must be able to use his discipline-specific tool directly. The tool must "interrogate" the CEP, which lets the user **load data** through his discipline-specific tool.

This is done via:

- Different **filters** described above (data status, role and identity of the user requesting access, etc.)
- Using a **neutral exchange format** (at least).

D4 - Discipline-specific tools

Specification integrators

Specification integrators are used primarily to initiate the project's IM. They can be used:

- **To import initial data** concerning the site, context and environment, such as GIS databases issued by a government agency.
- **Allocate** the client's **specifications** by space to a region or a primitive geometry.

We can thus "set the stage" for the project by defining:

- the **site** and its characteristics,
- the **specifications** of the prime contractor,
- the **organization** of the project.

Authoring tools

There are:

- **General authoring tools**: No discipline-specific perspective, purely mechanical, e.g., they allow modeling of the equipment used by or created for the project.
- **"Segmentable" discipline-specific authoring tools**: On the same model as the discipline-specific perimeters proposed later as the structuring of the data in the first levels. Each design specialty has its authoring tool, and similarly for calculation tools and "the *model view definition* "used by browsers outside the CEP.

All authoring tools must:

- be based on a database object allowing it to be saved in the **neutral format** initiated in the next chapter;
- have all the browsing **functions** required by the browser of the CEP.

Simulation tools

To simulate means to apply a scenario to an existing data set to derive a **behavioral response** of the system modeled.

This means any tool for strictly using read d**ata** to produce an analysis. The results are **mappings** of v**alues:**

- exportable as a document to be linked to these hypothetical objects
- or to be added as additional attributes to the said objects.

A new version of these objects is generated with the comment "analysis X performed on version Y of objects A, B, C, etc.".

The following diagram explains why it is essential that the results of simulations or calculations be **saved as values or mappings of values** onto objects (and therefore as attributes of the latter), and therefore **transmissible** via the neutral exchange format.

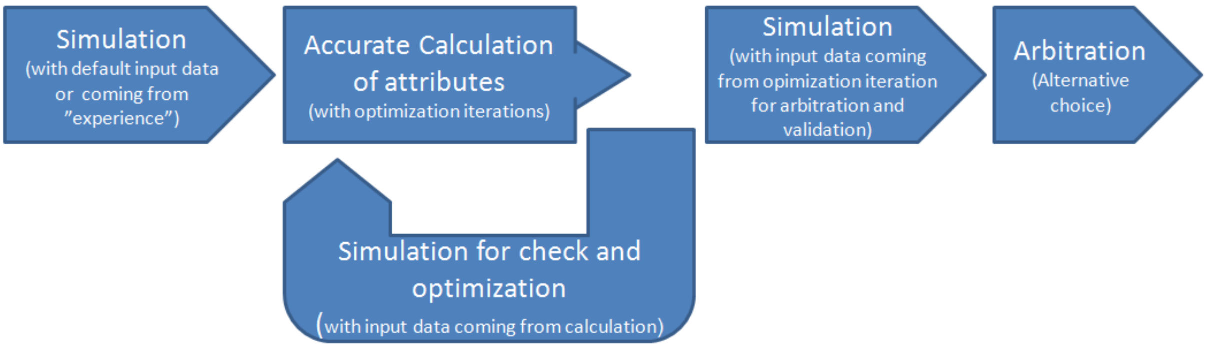

Figure D4-1: Diagram of iterative simulation

Calculation tools

To calculate means to dimension the component elements of the system of parametric objects which constitute a multi-discipline IM.

We understand by this term, the **use,** the **modification** and the **creation** of objects via a technical analysis. For example, in a structural calculation of reinforced concrete, we:

1. Perform a simulation by taking the structure outlined and loading it.
2. Analyze the results to optimize them.
3. Complete this work by specifying the model that best meets the needs expressed by the simulation.

D5 - Report on tools

On the collaborative exchange platform

The minimum functions required by the CEP are:

- Hosting of data:
  - storage
  - management of exchanges,
  - access regulation by profiles,
  - management of data flows (*Workflows*).
- The **exchange** platform to the discipline-specific CAD, calculation and simulation and project review tools, ideally through a neutral and open format (such as IFC in the building field).

Addition of functions

To these minimal functions are added the functions of:

- **clash analysis**,
- **project review** (navigation and arbitration of alternatives and clashes)
- **check of geometric rules** based on design standards.

These are the functional building blocks that must remain **interchangeable software** building blocks.

Overall remarks

The aim of this part of the deliverable is not to define all the requirements that constitute a functional, "performance-oriented" specification of a future system.

However, we can allow ourselves to hope that the **harmonization of** publishers' developments will see the emergence of:

- an **ecosystem of convergent tools**,
- a **standard** for the data model.

This will connect the world of **GIS** (for linear infrastructure and networks) and **the Civil Engineering BIM** (for engineering structures and buildings) in an **open XML coding** if the source remains in the public domain.

E - Data model

Introduction

The data model, the mainstay of the exchange standard

The preceding chapters show, from the functions expected and the architectural schemas, that the COMMUNIC global model requires a standard for exchanging information. This standard comprises:

- a shared data model,
- a neutral exchange format.

Note: The standard-setting process (which will include defining a data model) is the subject of Chapter F below.

An approach to basics, non-exhaustive

In the functional program, we discuss the data model and indicate what we think it is **essential** to take into account in the data model to conform to the COMMUNIC global model.

This chapter does not attempt to describe a data model that is ready to be applied, so do not seek the completeness and consistency of a detailed data model here.

E1 - General characteristics of a data model

Reference Model

To ensure the consistency of the IM, it is necessary to define a reference model.

Neutral format for sharing and archiving

The model is used to specify a neutral format for **the** sharing and long-term archiving of data from the IM. This neutral format is implemented in platforms by publishers of import / export software to **ensure the compatibility of their solutions** with this reference object model.

Discipline-specific software user guides

This model is also used to develop discipline-specific software user guides to **steer users** towards the use of the right functions and right proprietary objects, compatible with this reference object model.

Parameterizing of the PLM application

Finally, the model is used to parameterize an application of the PLM type**,** in particular to **configure its proprietary object model i**n accordance with project organization objects compatible with this reference object model.

Data processing objects constituting the model

The reference object model contains:

Type of data objects	Example
1. **"Constructive" objects**: objects actually constructed, that is to say objects defined by the COMMUNIC global model (see deliverable L1)	1.1: bridge pier
2. **"Resources"**: resources required to design, build and operate the infrastructure.	2.1: materials, temporary structures, data processing solutions to deploy for the project 2.2: stakeholders (designers, builders and operators) 2.3: *Workflow* or project schedule (with phases, tasks)
3. **"Containers"**: virtual or real aggregates of constructive objects or resources.	3.1: bridge 3.2: system involving drainage equipment for the structure
4. **"Relations",** which defines all the necessary combinations of relations between constructive objects, resources and containers.	4.1: bridge pier belonging to the bridge 4.2: bridge pier connected to the deck 4.3: pipe which is part of the drainage system

Attributes of data processing objects

To each of these computational objects, it is necessary to associate attributes (or properties).

Among these attributes are:

- One or more **geometric representations.** These correspond to the levels of development or modes of representation required for certain analysis disciplines.
- A positioning in absolute terms or relative to another object.
- **Association** with one or more materials.
- One or more sets of **technological properties** (non-geometric).

Nesting of the IM

The volume and multidisciplinary character of the data in the IM inevitably pose the **problem** of how to **store** it and how to **share** it.

Models nested like Russian dolls

It is unlikely to be possible to store all the data of a model in a single file. We must therefore consider storing the data in **network of files**.

Each file, corresponding to a partial model, can be:

- a description of a constructive object or a container that can correspond to **one lot of the project**,
- **a** special **discipline** (structure, fluid networks, etc.)
- **phase** of the project (e.g., APS, APD, etc..)
- **version** of the project
- **alternative form** of the project.

Example of nesting

A file nesting schema, or a *CityGML* file, can be used to **describe the overall project** on a territorial scale. This *CityGML* file refers to external IFC files, which allow you to describe in detail any particular element of the construction project:

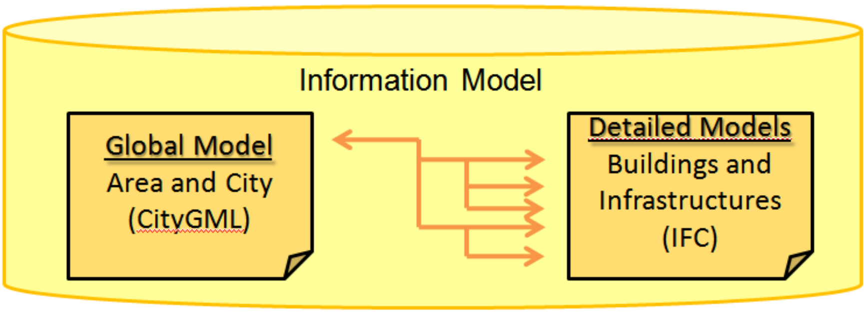

Figure E1-1: Example of links between partial models

Links between models to be managed by specific tools

This is known as nesting of models. It is managed by two types of tools:

- **Synthesis tools**, that allow us to verify the consistency of these sub-models and detect possible clashes.
- **PLM type tools,** which allow us to manage the entire lifecycle of the construction project by associating each sub-model with authors and reviewers, with planning elements, etc.

E2 - The COMMUNIC data model

Structuring of physical objects in levels

The model must be based on "**physical" objects,** that is to say the future components of the structure to be built.

Objects: the elements that structure the model

The term "object" is used here not in the sense of a computing object representing a characteristic, relation, rule, etc., but to refer to a p**art of the structure** that is geometrically defined and will actually be built.

The examples of items found in infrastructure illustrate the **diversity of the physical objects** in terms of domain and level of detail. Examples of objects that are computing objects to be manipulated rather than physical objects are also given. They are usually items of information.

This assumption underlies the model database.

Examples of physical objects	Examples of data objects
diversion view of a drainage system embankment body bridge pier tunnel reinforcement of bridge deck concrete	approval date of a record reference speed permissible stress of a material color of a railing axis of the infrastructure cost of a VMS

The structure to be built is structured into levels

The visions we want to obtain of the structure, and the progressive character of the studies, lead us to organize the structure into levels containing increasingly detailed objects.

The data model must be designed with the following first 3 levels:

- **Level 0 - the project**

This level is always reserved for the overall object of the project. So, physically, it is the **entire structure to be built**.

- **Level 1 - functional structures**

This level corresponds to a breakdown of the project into functional objects. In fact, an infrastructure project is divided into parts usually called "structures", each of which performs a practical function.

Object of level 1	Function to be performed
Motorway	Allow vehicles to travel on the motorway
RN138	Keep the RN 138 open to traffic
Power line	Transmit electric power across the project
Stream	Let the water of the stream flow
Subgrade	Support the project

- **Level 2 – discipline-specific structures**

This level corresponds to a breakdown of each functional structure into discipline-specific objects (or fields) that must be mobilized to build it.

Object of level 2	Work done by
Engineering structures	Companies specializing in engineering structures
Earthworks	Excavation contractors
Drainage	Drainage contractors
Pavements	Pavement contractors

The most detailed levels are defined on a case-by-case basis taking account of the specificities of the **project** and **fields** concerned.

One reason for deciding how to break these levels down is that projects are generally estimated at the intersection of levels 1 and 2 (types of structures / nature of work).

Example of structuring

The diagrams below illustrate the logic of this structuring into objects by level, and the transversal character of the systems.

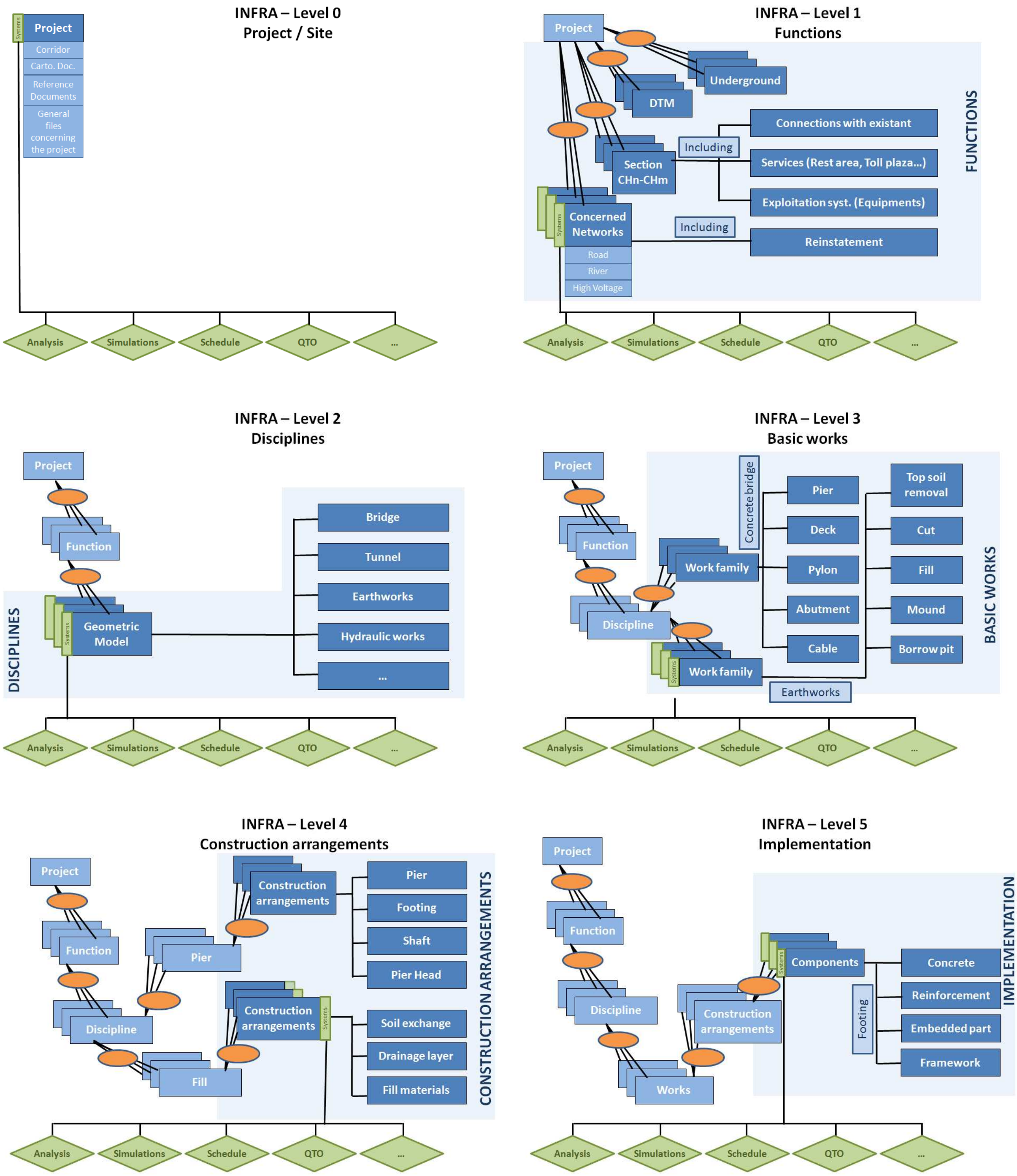

Figure E2-1: Example of structuring of a project into objects by levels

Transposition of the IFCs

There is an analysis of the transposition of the building, bridge and infrastructure IFCs in Appendix 3.

Information attached to physical objects

The data model must organize information related to objects.

Any information relating to the project is traceable to an object

Given the above structuring into objects by level, it is possible to trace any information about a project to an object.

The **nature** of the information lets us select an object to which the information is relevant. It is usually only the object at the highest level that concerns us.

Three categories of information attached to an object

The quantity of information that can be attached to an object is large. We must therefore organize its storage. We have decided to retain three categories of information:

- information that allows **geometric definition**,
- information that characterizes the object **-** its **attributes**,
- information about relations with the attributes of other objects **- links.**

Geometric definition

This is all the information that defines:

- the v**olume** of the object, its external or internal surfaces,
- its **positioning** in space.

Attributes

This is all the information that is specific to the object and **characterizes it.** We can cite for example: the type of material, weight, cost, completion date.

Links

These are **constraints or rules to follow** between the attributes of the object and the attributes of other objects.

These links could include for example:

- geometry, with a surface that must be in contact with a surface of another object,
- scheduling, with one object to be implemented after another,
- a cost, which is the sum of the costs of "child objects"、
- a load related to the weight of another object,
- a co-visibility.

Characteristics of each item of information

The IM must manage information. So all information must be precisely defined, for example:

- the owner,
- public or private,
- confidentiality,
- status,
- date of coming into validity.

Systems that cut across the structuring into levels

The global COMMUNIC model has identified transversal systems that must **be managed as well as** levels in the structuring of objects.

These systems must be defined **case-by-case** for each project, but the data model must be designed to be able to manage them.

Links are reserved to identify:

- the **systems** to which the object belongs,
- the **attributes** which are useful in the management of these systems.

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F - Roadmap to a COMMUNIC exchange standard

Introduction

Objective

Standardize the data model

This chapter describes how to standardize the **COMMUNIC neutral data model a**s presented in Chapter E.

Choice of standard of IFC type

Given:

- the level of detail expected by COMMUNIC partners (engineering firms and construction companies)
- the maturity of the IFC format,
- work already completed for engineering structures (the IFC-Bridge project)

it is an **extension of the IFC standard** which is referred to for the standardization of the COMMUNIC data model.

Contents

The following list describes the modules in Chapter F:

Module	Contents
F1 - The approach to developing a standard	**Procedure to define** an extension of the IFC standard.
F2 - Existing standards	**Hints and sources of inspiration,** drawn from existing standards (IFC, CityGML, LandXML, etc.) to complete this process of standardizing the COMMUNIC model.
F3 - Development tools	Some **software components** developed to support the inclusion of the new standard by software publishers.

Roadmap for a COMMUNIC exchange standard

If we follow the concept of the ***BuildingSMART* Aquarium,** the process of developing an **IFC Infrastructure Standard** is normally as follows.
It should be noted that this **approach** is obviously **iterative, w**ith gradual introduction of new processes and discipline-specific views.

Step	Approach	Description
1	Medi@construct request	Formulation of the request for a **new IFC project** to its *BuildingSMART* chapter, namely the Medi@construct association for France.
2	Internationalization	Search for at least two other international *BuildingSMART* chapters ready to support the project. For infrastructure, this should not pose any major problem, in view of the fact that the **German, Japanese and Scandinavian** chapters have already expressed interest.
3	Organization	Assembling the project with the appointment of a "***Project Leader*** "and a "***Technical Leader"*** . For this pair, a Franco-German tandem is most likely. At this stage we should also identify the *BuildingSMART* **experts,** a priori members of the group (MSG*Modeling Support Group*), who will accompany us.
4	Associating publishers	The Aquarium concept combines the authoring and implementation phases. It would certainly be beneficial to involve a few software companies, which **validate** the **standard developed** by implementing it.
5	Formalization of the process	**Authoring** then begins with the formalization of the process, using the IDM formalism (*Information Delivery Manual* - http://www.iai.no/idm/), starting over again from the work of the global COMMUNIC model and the potential contributions of other chapters. This involves specifying, in the IDM formalism, the **processes** described in the global COMMUNIC model (deliverable L1).
6	Translation into discipline-specific views	From these IDM formalisms, we extract discipline-specific views which are formalized using the MVD mechanism (*Model View Definition* - http://www.blis-project.org/IAI-MVD/). These are used to precisely specify the requirements in terms of *mapping* to the existing IFCs or the creation of new entities. This involves specifying **t**he COMMUNIC **data model objects**, as outlined in Chapter E.
7	"*Mapping*"	*Mapping* and IFC extension work is then carried out by MSG experts who produce an **EXPRESS schema** for IFC-Infrastructure. This schema should be a **combination** and an **extension** of the IFC 2X4 and IFC-Bridge schemas. The next module in this chapter shows initial mapping paths.
8	Development toolbox	The EXPRESS product schema is then used to **produce SDK for** read / write of IFC-Infrastructure instances. Example: use of the Expressik automatic generator to automatically produce SDK from the EXPRESS schema. Examples of SDK are described in the next module.
9	Definition of tests	A set of IFC test files **consistent with the IFC-Infrastructure schema i**s produced, more or less manually. It is used to test the interfaces.
	Test procedures	**Automatic test procedures** and **a reference viewing tool** may also be developed (e.g., extension of the CSTB's eveBIM *viewer*).
10	Implementation by publishers	Software vendors are now **implementing a new standard** based on previously developed components.
11	Industrial validation	An industrial validation phase is being conducted by users of the **interfaced software tools in the various disciplines.**

F1 - Use of existing standards

"*Mapping*" standards

In this section, we propose to interpret the COMMUNIC data model objects (Section E), with the existing entities of the following standards:

Standard	Interpretation
IFC (ISO 16739)	This comprises 800 classes of objects in its 2x4 version. It will be officially released in late 2010. It already provides a comprehensive standardized model for the IM of buildings, with architectural, structural and HVAC elements. IFCs are now available for import / export of most of the new CAD software for buildings (Autodesk Revit, Graphisoft ArchiCAD, Allplan Nemetsheck ...). The IFC 2x4 incorporate geographical and geopositioning elements inspired by CityGML, which can locate the building in its context. http://www.buildingsmart.com
IFC-Bridge	IFC-Bridge is an extension of the IFC specific to engineering structures developed by SETRA, with technical support from the CSTB in the official context of BuildingSMART and in cooperation with the French, Japanese, Scandinavian and German chapters. This model, known to be quite comprehensive for bridges, has not yet been formally incorporated into the IFC nor implemented by software companies, pending a more complete draft of a merger with an "IFC-Road" or "IFC-Infra" model.
CityGML for the global IM of cities	*CityGML* has been developed by the international organization OGC (*Open Geospatial Consortium*) and now adopted as **Standard 3D** by INSPIRE. For France, IGN is a recognized expert in *CityGML* and participates actively in its development within the OGC. Solutions such as IGN's Bati-3Dor Carto-3D , or *LandExplorer* from Autodesk, already offer CityGML import / export interfaces. http://www.citygml.org/
LandXML	*LandXML* offers a **neutral XML format** for road layout exchanges with descriptions of axes in plan, longitudinal profiles and cross sections. This format, implemented by Bentley and Autodesk, has not been adopted by any official standards group. It could be the primary **source of inspiration** for an IFC Road. http://www.landxml.org/
GeoXML (ISO 14688-3)	As part of the normative documents developed by ISO TC182, an e**xchange** format has been defined in standard ISO 14688-3, Geotechnical investigation and testing - Naming, description and classification of soils - Part 3: Electronic data exchange on the naming and description of soils.

Usability

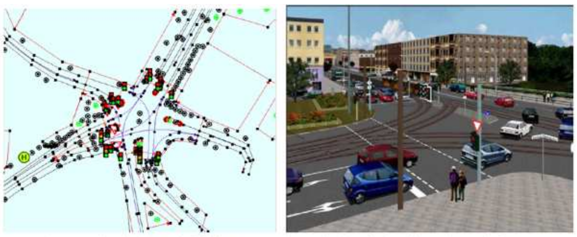
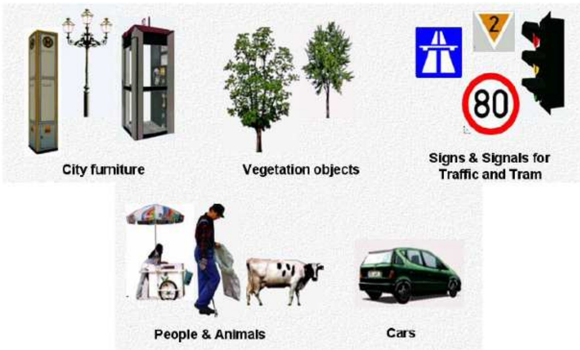
These standards give us the inspiration for our COMMUNIC. standard They can be used in 2 ways:

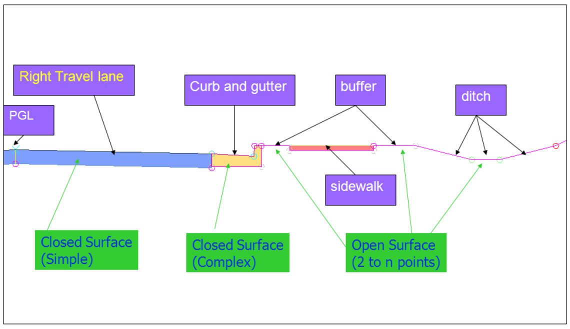
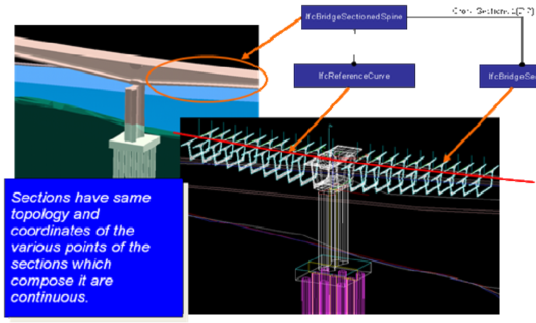
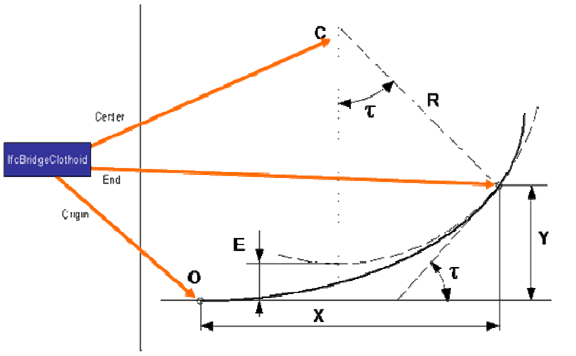
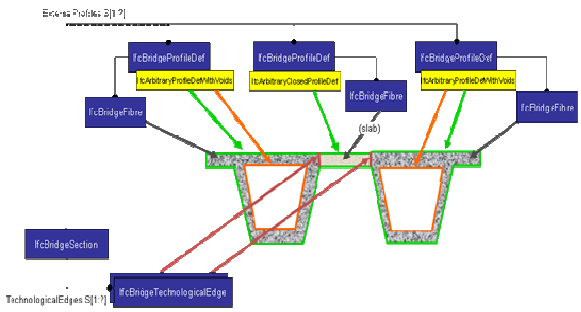
Inspiration — They are an inspiration for objects and attributes, to **create new entities missing** from the target standard (IFC).

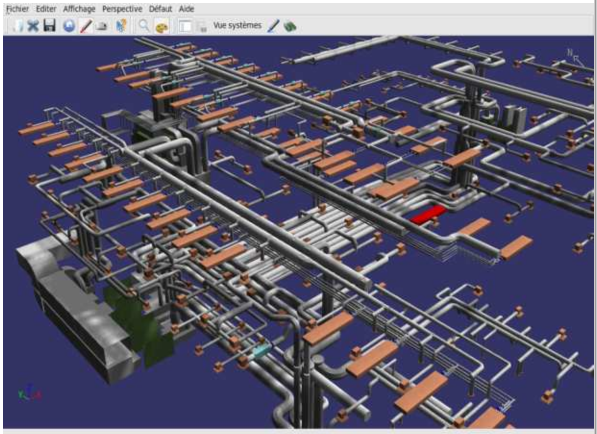
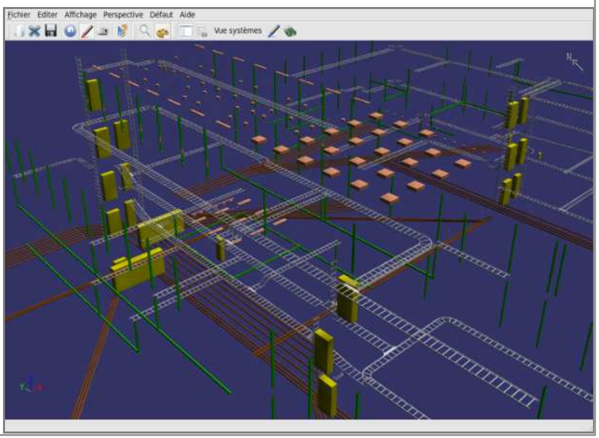
Establishment of links — They help establish a **link between an** IFC **object** or attribute and an associated **external file** defined in another standard (eg GeoXML).

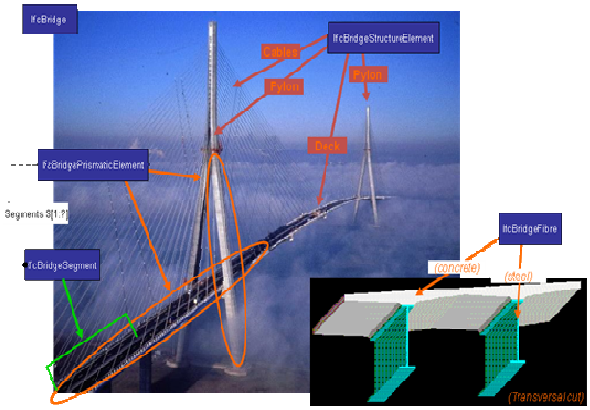
Examples of use

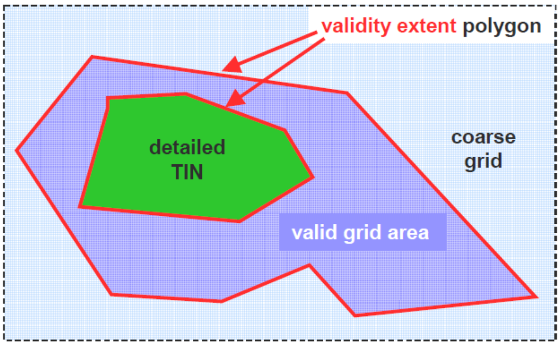
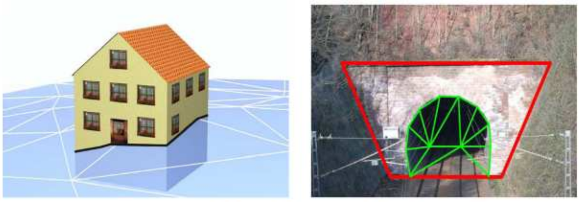
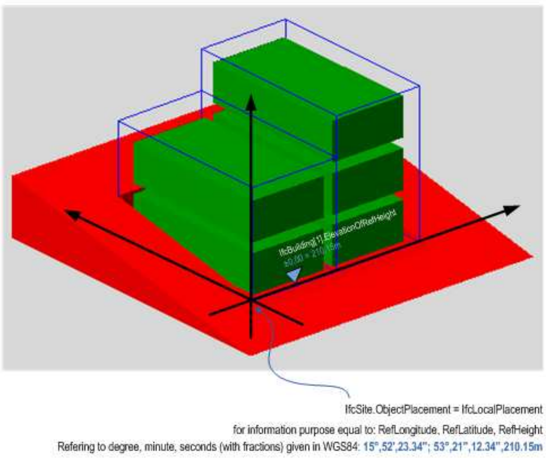
The following table shows paths for *mapping* COMMUNIC model objects. It indicates, for standard sources, the objects that could be taken as inspiration for the "IFC-Infra" model.

COMMUNIC objects	*Standard source*	Possible mapping
Transport routes	**CityGML**	**TransportationObjects**  Fig. 37: Complex urban intersection (left: linear transportation network with surface descriptions and external references, right: generated scene) (source: Rheinmetall Defence Electronics).
Signs, safety equipment	**CityGML**	***Prototypic objects***  Fig. 7: Examples of prototypic shapes (source: Rheinmetall Defence Electronics).

COMMUNIC object	*Standard source*	Possible mapping
Profile of the road or engineering structure	**LandXML**	
	IFC-Bridge	**IfcBridgeSectionSpine** 
		IfcBridgeClothoid 
		IfcBridgeProfileDef 

COMMUNIC object	*Standard source*	Possible mapping
Fluid networks	**IFC 2X4**	**IfcPlumbingFireProtectionDomain** **IfcHvacDomain** **IfcElectricalDomain**  

Bridges	**IFC-Bridge**	**IfcBridge, IfcBridgeStructureElement, IfcBridgeSegment** 

COMMUNIC object	*Standard source*	*Mapping* possible
Industrial Buildings	**IFC 2X4**	**TBA**
Hydraulic Structures	**TBD**	**TBA**
Earthworks	**CityGML**	**Digital Terrain Model (DTM) → to complete**  Fig. 22: Nested DTMs in CityGML using validity extent polygons (graphic: IGG Uni Bonn).  Fig. 4: Closure surfaces to seal open structures. Passages are subsurface objects (left). The entrance is sealed by a virtual *ClosureSurface*, which is both part of the DTM and the subsurface object (right) (graphic: IGG Uni Bonn).  Fig. 5: *TerrainIntersectionCurve* for a building (left, black) and a tunnel object (right, white). The tunnel's hollow space is sealed by a triangulated *ClosureSurface* (graphic: IGG Uni Bonn).
Site / context	**IFC 2X4**	**IfcSite** 
	CityGML	**LanduUse**
Geotechnical	**GeoXML**	**TBA**

F2 - Toolkit

Common software components

To implement standards like IFC and CityGML that are very rich and therefore complex, software publishers must rely on common software components to **facilitate their implementation.**

The toolkit includes:

- *standard development kit* (SDK)
- reference visualization tools
- tests and testing procedures.

Standard Development Kit (SDK)

Programming libraries

Libraries (SDK / API) in various languages (C + +, Java, etc.) are integrated into the discipline-specific software (CAD, analysis, etc..) to ensure **connection** (read / write) **with data formats** associated with standards.

For IFCs

Under the eXpert project (ICT-SME 2010), CSTB has developed such a library in **C + + f**or IFC.

This IFC-SDK is now already o**perational with a coverage of 100%** of the IFC 2X3 standard, currently implemented by most building software publishers (Autodesk, Nemetscheck, Graphisoft, etc.).

It is available in **Open Source** on the free software site from the European Community OSOR: https://www.osor.eu/projects/ifc-sdk.

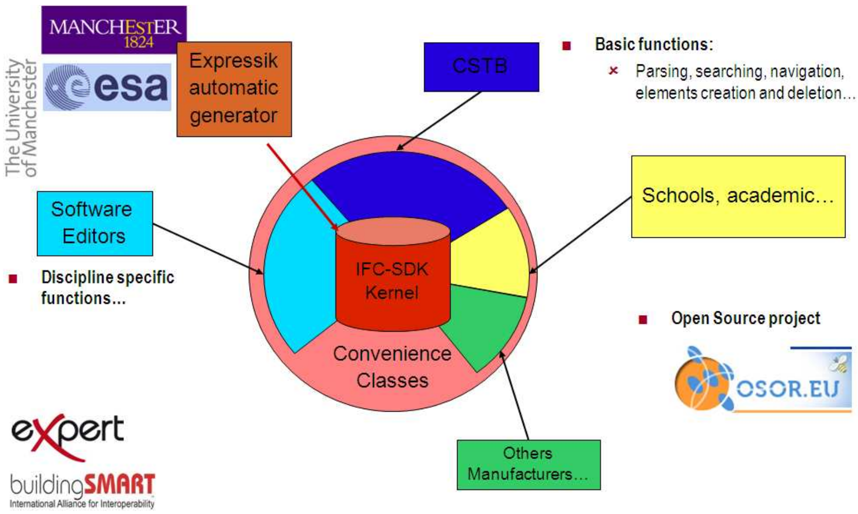


Figure F2-1: Example of programming library

The above example shows the open source programming library IFC-SDK, the result of cooperation of CSTB with the **European Space Agency and the University of Manchester**.

For CityGML

Under the ANR TerraMagna, CSTB has developed a prototype SDK for CityGML.

For its own needs as part of its **Bati-3D** and **Carto-3D** offerings, IGN has also developed this kind of component to read/write the CityGML format.

Reference visualization tools

Visualization tools for reference:

- facilitate **understanding** and n**avigation** in data standards;
- are involved in v**alidation** interfaces for discipline-specific software.

For buildings

At the building and IFC level, CSTB has developed a visualization tool, **eveBIM**. It can:

- upload IFC files
- visualize them,
- explore them,
- possibly enrich them for coupling with simulation tools.

This tool is **nearly operational.** It has entered a beta testing phase with buildingSMART representatives and some industry testers.

For the urban environment

On a territorial and city-wide scale, CSTB has developed the **eVEGA** software package. It has the same functions as for buildings.

Under TerraMagna, a CityGML format file **import prototype** has been developed in eVEGA.

Tests and test procedures

There are suites of test cases and automated test procedures. They facilitate **validation** of software interfaces, and thus prepare them for their **certifications** with buildingSMART.

An existing service to be improved

BuildingSMART already offers such services, particularly through its new GTDS server.

However, all software publishers and end users of software, a priori certified, believe that these services must be substantially **improved**.
See: http://www.iai.hm.edu/