MIN^{n}D National Project

Interoperable Information Modeling for Sustainable Infrastructures

Summary of Phase 1

June 2016

(version dated 10/06/2016)

Grant agreement no. 13 MGC S 007

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Contents

Contents ... 2
1 Introduction ... 3
2 Use cases in phase 1 ... 4
2.1 UC1 – Standardised use cases extended to infrastructures ... 4
2.2 UC2 – Roadway lifecycles ... 6
2.3 UC3 – IFC-Bridge ... 9
2.4 UC4 – Project review ... 12
2.5 UC5 – Cost control through modelling ... 14
2.6 UC6 – Infrastructure and environment ... 18
3 Themes in phase 1 ... 20
3.1 Theme 0 – Observatory ... 20
3.2 Theme 4 – Legal and contractual aspects ... 25
4 Transfer and promotion ... 26
4.1 EDUBIM 2015 ... 26
4.2 Promotional activities ... 27

1 Introduction

This report summarises the work done within the MIN^{n}D national project during **phase 1, which ran from April 2014 to January 2016**, following the Constitutive Assembly for the project held on March 24, 2014.

The first few months of the project were spent setting up the partnership, which was consolidated in 2015, and the working groups implementing the research programme.

As of January 2016, fifty organisations are members of the project (http://www.minnd.fr/le-projet-minnd/partenaires/):

During the first phase, the MIN^{n}D research programme focused on problems identified as covering several processes, in order to create a base for discussion during the subsequent phases. These subsequent phases will in turn draw on other representative practical cases of the problems not dealt with during phase 1.

The phase 1 programme was therefore structured around **six theoretical use cases** (UC). The resulting work will feed into the discussions on theme 1 (Analysing uses), theme 2 (Experimentation) and theme 3 (Information structure):

- UC1 – Standardised use cases applied to infrastructures
- UC2 – Roadway lifecycles
- UC3 – IFC-Bridge
- UC4 – Project review
- UC5 – Cost control through modelling
- UC6 – Infrastructure and environment

These six use cases were examined by six working groups, resulting in **deliverables, which are described very briefly in this summary**, and which have been made available to MIN^{n}D partners.

Two themes were also active during phase 1:

- Theme 0 – Observatory, notably through the organisation of MIN^{n}D campus seminars
- Theme 4 – Proposals to adapt the regulations

The **results of themes 0 and 4** are also summarised in this document.

Themes 1 to 3 were not formally studied in phase 1 as the associated working groups have not been set up, and they are not the subject of any deliverables as yet.

2 Use cases in phase 1

2.1 UC1 – Standardised use cases extended to infrastructures

2.1.1 Objectives

The initials objectives for this use case were to:

- transpose buildingSMART's "BIM Uses" into French and establish the scope of each use case;
- obtain the specifications for the functions or systems taken into account in each use case, and in consequence those of their constituent objects (geometry and attributes);
- establish the interfaces/impacts between the systems (links between systems and objects);
- configure existing tools (such as IDM (Information Delivery Manual) V2.0).

These objectives were clarified and completed by the UC1 working group with a view to:

- making relevant proposals for developing **BIM execution plans**;
- highlighting **the differences between and complementary elements of** the overall project (general BIM uses) and its component structures (specialised BIM uses);
- adapting the **lifecycle** phases to the specific nature of infrastructures;
- taking into account the concepts of **systems engineering** in the analysis of infrastructure organisation;
- incorporating the principles and methods of **requirements management**;
- orienting the conclusions of the discussion towards the following targets: standardisation bodies, other MIN^{n}D working groups, BIM end users and software publishers.

The work on UC1 led to the production, at the end of phase 1, of a partial deliverable in two parts:

- the objectives, context, approach and roadmap for phase 2;
- partial elements of the final phase 2 deliverable with the summaries of discussions already held on the principles for structuring and then managing information.

2.1.2 Context, issues and approach

The deliverable reframes the UC1 discussions with:

- **the issues**: owner demand is high, yet the databases, methods and tools are neither consistent nor complementary, and interoperability is still not considered a prerequisite;
- **the context**: non-French construction industry actors, supported by their governments, are very active in BIM for infrastructures. Although the conclusions and proposals of the MIN^{n}D project are generating interest, other parties might not perhaps wait for them, despite our active presence in buildingSMART. The BIM developments for buildings are valued and effective, but the developments required for infrastructure BIM need to be significantly more detailed and complex. This specific element (reasoning on systems in addition to structures) has not yet been effectively assimilated by the actors;
- **the aims**: these are to provide the bodies in charge of standardisation, and software publishers, with the principles for structuring the information linked to infrastructures. They also include

showing the end users of BIM how changes can be carried out now, before standardisation is complete, before the software is available and interoperable, and before cultures have been adapted to the sharing of information on the one hand, and modern methods such as systems engineering or requirements management on the other;

- **the approach**: the working group analysed various approaches or methods:
  - the principles outlined during the COMMUNIC research project;
  - the buildingSMART approach;
  - the RO-DT approach (Reference Model of Open Distributed Processing);
  - systems engineering;
  - requirements management.

  Certain proposals were made using real-life cases:
  - a schematic plan of the emergency and service areas of a highway;
  - the land-related tasks for an infrastructure.

A seminar with two sessions was organised to share points of view with actors that were not represented in the working group.

2.1.3 Principles for structuring then managing information

The second part is a provisional and partial version of a final deliverable for phase 2. It will be dealt with under theme 3 ("Information structure") in phase 2.

The deliverable recalls two basic rules that must be followed to structure the information regarding an infrastructure:

- **Integrate the infrastructure into its broad environment** (region, networks, inhabitants, fauna, soil and subgrade, etc.). In this respect, an infrastructure constitutes a system that meets a need and is incorporated into an environment. This makes it possible to define the scope of the infrastructure, i.e. its sub-systems and external systems, from the beginning of the project. It also makes it possible to draw a distinction between the infrastructure and the facilities it comprises (civil work structures, buildings or tunnels, for example) that are not infrastructures.
- **Always take needs as a starting point**. This principle should be well-known by all actors, but systems engineering and requirements management formalise its application: do not focus too soon on the solutions if the needs have not been critiqued and validated.
  - The "Project Owner" identifies the needs and, at the end, approves the product.
  - The "Project management and design team" records the needs given by the Project Owner, transforms them into requirements, and then validates the product as meeting the requirements.
  - The "Designer" and "Contractor" design and produce the components (objects, processes or tools) of the project to meet the requirements, then check that they are duly compliant.

The deliverable also proposes principles for structuring and then managing the information regarding an infrastructure:

- **By system**: to do this, systems engineering provides a rigorous method with an approach along three lines:

- an architectural line with three successive views: the operational view (needs), the functional view (requirements) and the organic view (components);
- a line of progression in terms of complexity (from design of the components to the uses to which they are put);
- a line of progression in terms of maturity and integration (from the concepts to the assembly of validated components).

- **By object**: the infrastructure is composed of physical objects. The principle is to geolocate these objects, establish their volume and attach the information to the objects it concerns. This allows:
  - all actors to view an object, a group of objects, a structure or the overall infrastructure;
  - the creation of views adapted to uses (by actor, by system, etc.);
  - sorting based on the location of the information.
- **By lifecycle phase**: at a global level, the lifecycle must show the main phases of assembly, design, production and operation. The working group has shown that the lifecycle should be divided as follows:
  - into a global lifecycle with general tasks that cannot be split up and dealt with separately for the specific structures;
  - into as many lifecycles as are required by the subdivision of the product into specific structures (civil work structures, earthworks, operating systems, etc.).

  At a more basic level, a V lifecycle must be set up to manage the maturity of the systems and objects.
- **By actor**: the number and diversity of actors involved in an infrastructure means it is absolutely necessary to structure the panel of these actors: direct actors, indirect actors, influencing actors and stakeholders. In addition, the deliverable summarises the founding principles of the following two methods analysed by the working group, several elements of which have been reproduced above:
  - systems engineering;
  - requirements management.

Finally, the deliverable provides a **glossary** of the terms used, which should be incorporated into the general MIN^{n}D glossary.

2.2 UC2 – Roadway lifecycles

The UC2 use case deals with **the roadways that are part of a linear infrastructure** and their development throughout the **infrastructure lifecycle**, from programming, design and construction up to operation, servicing and maintenance.

The UC2 working group brought together the key actors involved in the design, construction, operation and maintenance of infrastructures, as well as PLM (Product Lifecycle Management) specialists.

The roadways constitute the main asset taken into account in an asset management system. With regard to service life, design rules, interactions with users and the costs associated with servicing and maintenance, it is necessary to structure roadway data in order to:

- know the roadway characteristics;

- know the state of the roadways at any time;
- plan for monitoring and servicing needs.

Structuring roadway data should make it possible to have all the necessary information available so that the following can be known at any time: the level of service offered to users (surface characteristics), the state of the asset and urgency in the event of damage. It is therefore helpful to take an inventory of all data relating to roadway design, construction, environment and monitoring.

2.2.1 Approach adopted

A review of the state of the art was firstly carried out to assess existing techniques in the field of road infrastructure management, with respect to:

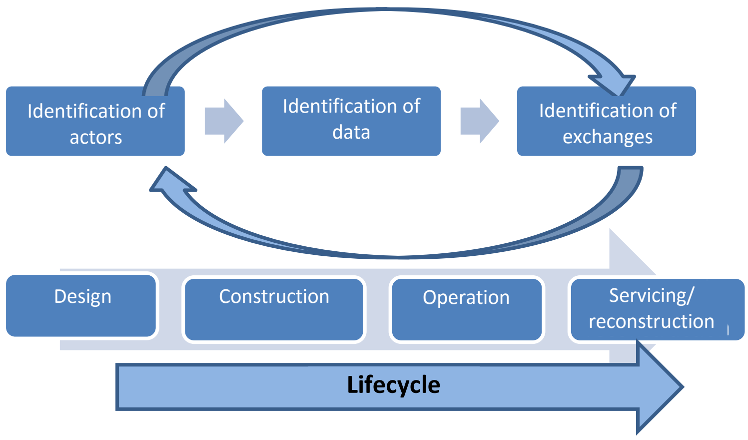
- the actors that manage roads over their lifecycle,
- the information exchanged by these actors,
- the processes in which these exchanges take place,
- current exchange tools.

More than a literature review, this study of the state of the art assesses the situation in the French context to start with, followed by the European and international contexts, and of course is based on previous and ongoing projects and initiatives.

The use of BIM during the roadway lifecycle is an opportunity that forms part of the approach already taken for this theme through the ongoing implementation of a database and of GIS (Geographic Information Systems).

The approach involved considering the following questions:

- Who are the actors across the lifecycle?
- What are the useful, used data, .., across the lifecycle?
- When or during which project phases do the exchanges take place?
- What information is exchanged between the actors?



The work led to the precise definition of:

- the **actors** (concession holder/project owner, designer, contractor, operator);
- the **static and dynamic data** required during the design/construction and operating phases;
- the **project phases** (design, construction, operation).

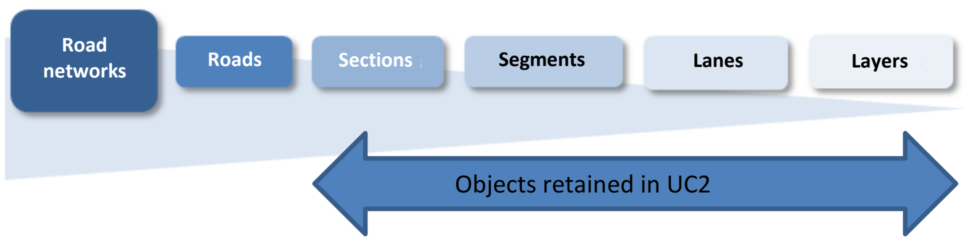
2.2.1 Structuring of data

An exhaustive model of the data associated with the roadway, integrated into the information model of a road infrastructure project, was produced for the various phases of the project. This model includes all road categories (highways, national primary and secondary roads, regional roads, urban roads), with the corresponding guidelines and standards, and covers both new and existing structures. A representation of the various viewpoints and items of information exchanged, and a model of the key processes are also offered.

A road project may be subdivided into several interlocking elements. Each datum can then be associated with **a unique object**: the road networks (owner unit), the roads (political-administrative unit), the road sections (design unit - initial construction), the road segments (unit of behaviour or state), the lanes, the layers.

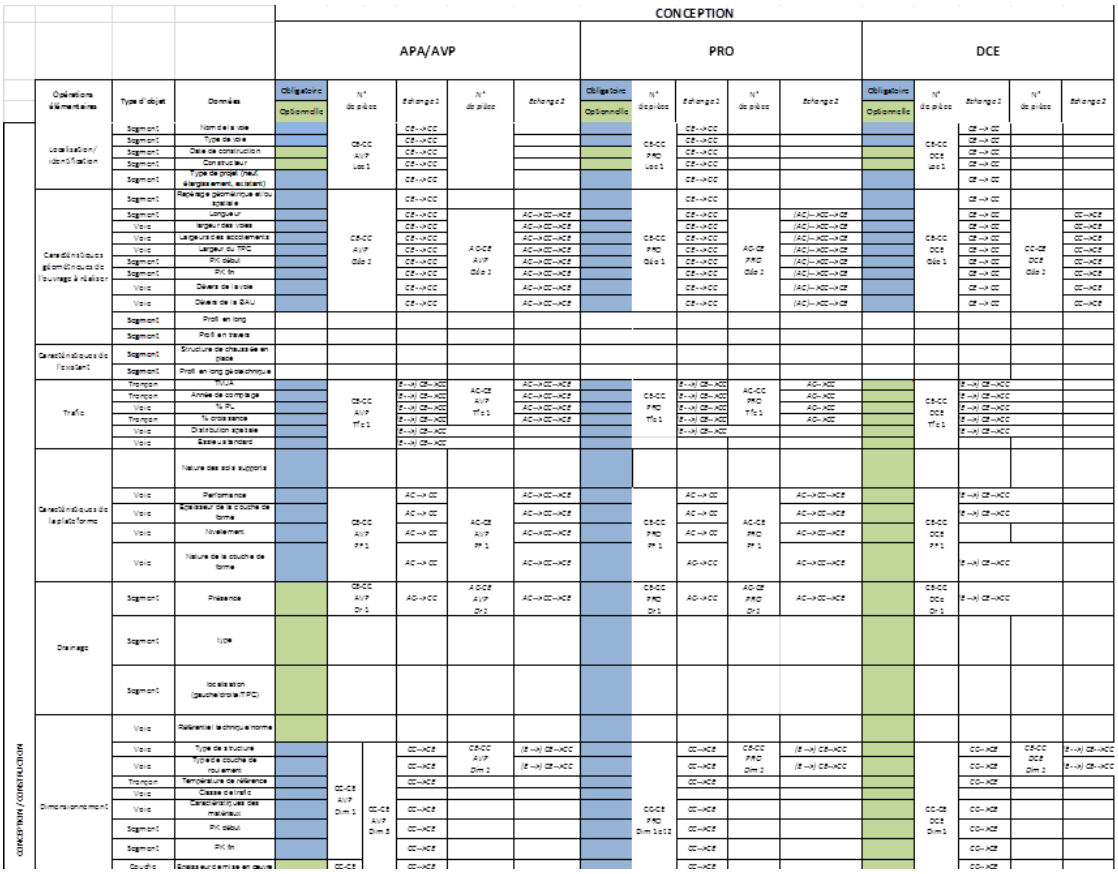
The following breakdown was adopted for structuring roadway data.

- Object: Section
- Sub-object N-1: the segment
- Sub-object N-2: the lane
- Sub-object N-3: the surface and materials



This approach therefore associates the notion of spatial subdivision with that of subdivision by object/component. It does not incorporate the notion of functional subdivision, which is only sensible and useful when we are looking at the network level, particularly where roads are being prioritised to manage their servicing.

Finally, the model was formalised via a matrix with several entries, grouping together all the data, their allocation to the various objects and the flows of exchanges between the various actors during the different project phases (see extract below):



2.3 UC3 – IFC-Bridge

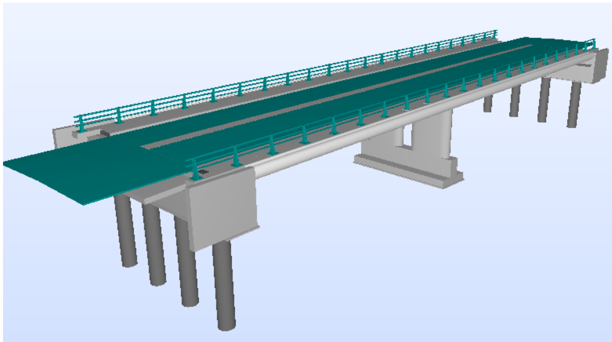
IFC-Bridge is an extension of the IFCs[1], specific to civil work structures, developed by the French transport research division SETRA, with the technical support of the CSTB (French Scientific and Technical Center for Building), as part of the official buildingSMART framework and through cooperation between its French-speaking, Japanese, Nordic and German chapters. This model, recognised as being fairly complete for bridges, has not yet been formally incorporated into the IFCs or implemented by software publishers.

As part of phase 1 of the MIN^{n}D project, in cooperation with the openINFRA initiative (with the backing of buildingSMART International), the **current obstacles** to the use of IFC-Bridge were identified and an **action plan** established to break down the barriers standing in the way of this extension being deployed.

[1] The IFC (Industry Foundation Class) format is an object-oriented file format used by the construction industry to exchange and share information between software packages.

2.3.1 Identification of deficiencies

An assessment of the current state of applicability of IFC entities to the establishment of an information exchange model for bridge construction was carried out in phase 1. This study is based on understanding of the ISO 16739 (IFC) standard and the work to prepare for an IFC-Bridge extension. It is also based on the "use case" analysis that led to the production of IFC exchange files based on the IFC ISO standard, therefore with building-oriented entities.



Regarding civil work structures, there are two categories of deficiency in terms of the IFCs:

- regarding the existing IFCs: incomplete implementation (extrusion, Boolean operations, etc.) or uses that are not really oriented towards the field of infrastructure (prestressing, etc.);
- regarding the field of civil work structures and the environment in which they are based: a need for new entities to be developed.

These two categories are detailed in the deliverable entitled "IFC-Bridge State of the Art & Missing Concepts", written in English and available as part of the project. The deliverable concludes by identifying the concepts that are currently not correctly supported and proposing how the missing entities could be developed. The proposals must now be **taken up by an international development team** so they can be integrated into future versions of the IFCs.

It is also important to tackle these issues in the broader framework of the full set of information and models/simulations vital to the design-construction of structures as part of a "lifecycle" approach.

2.3.2 Dictionary

The aim of this working group was to create a **multilingual data dictionary for the domain of bridges**. A data dictionary comprises a library of objects together with their attributes, which describe the relationships between the objects as well as their properties. It thereby makes it easier to share and exchange information on the products manipulated.

In this study, the dictionary relates to the concepts used in the sector of civil work structures. This data dictionary therefore includes the constituent elements of bridges together with their English and French translations, descriptions, hierarchical links and characteristics. The aim of this data dictionary is to define the constituent elements of bridges so as to describe all types of bridge. Its comprehensiveness will be validated on a bridge project, for each design phase of the project. The dictionary will eventually be integrated into the buildingSMART data dictionary (bSDD).

The initial work has been finalised in compliance with the AFNOR/PPBIM standard (XP P07-150). It now remains to **finalise integration into the bSDD**, the international platform for the definition of construction objects.

It is therefore necessary to make use of all the concepts and tools available, with the support of the experts that have made this platform available to users, and consolidate the work done in order to check consistency with previous dictionaries.

2.3.3 Information Delivery Manual (IDM)

Work done during the first stage of phase 1 led to the publication of an Information Delivery Manual (IDM) as part of the project to extend the IFCs to the domain of bridges. This IDM should fully cover the domain in a holistic manner in line with the most advanced professional practices. Its objectives are to fully explain **the processes followed** for a particular publication, and to **justify their relevance**, via the example of a bridge type that is sufficiently generic and common.

The approach taken was to start by following a line of de-integration/integration, intuitive for professionals, that detailed the components according to three views: the operational view (question: WHY is the bridge necessary? This constitutes the space of the problem posed), then the functional view (question: WHAT should the bridge do?), and finally the organic view (question: HOW or OF WHAT is the bridge made? These last two questions constitute the space of the solution). This subject was dealt with in a first Excel table, then projected into a second table over the lifecycle, which details all the states of the bridge components from creation to dismantling. During this last stage, it is possible to provide information on data exchanges (actors, content, phase) by using the BPMN system, for example.

Due to time constraints, the work provided during phase 1 only made it possible to partially complete the IDM. It was however possible to **validate the pertinence of the process and approach followed, and identify all the major issues** that the extension of the IFCs and IDM should aim to resolve to fully cover the domain.

In conclusion:

- **The IFCs are well-suited to the organic description of structures, but must be completed to ensure satisfactory cover of the needs of professionals** (in particular, with regard to the elements describing the physical environment into which the structure must be integrated, and the elements relative to the procedural geometry of the solids generated that are vital for modelling or constructing these elements).
- **The IFCs are also capable of describing the functions of structures, but are still insufficient or too rarely completed** to fully cover the domain, and in particular all the functional modelling for bridges (traffic, mechanical resistance, foundations, etc.).
- **The IFCs are not appropriate for the operational views, and must be complemented by other categories to cover these views and manage the needs and requirements** attached to the elements from the operational view up to the organic view; this management is vital to a full and comprehensive bridge verification and validation process. Having said that, this complementary context must be made explicit to allow development of an IDM that is truly suited to the needs and practices of the profession.

2.3.4 Implementation methodology

This action has made it possible to create a template that those in charge of developing future IFC standards could use for structures in the field of civil engineering infrastructures. This was achieved by harnessing the lessons learned over the past 18 months by the participants in the UC3 IFC-Bridge use case. More specifically, this work was done by:

- assessing the various global initiatives in the domain of infrastructures;
- compiling experiences and lessons from the UC3 sub-groups;
- highlighting the importance of a few key concepts such as the IDM (still fairly under-developed), MVD (Model View Definition – implemented fairly effectively), procedural geometries (rarely

implemented in export formats) and glossaries (of which there are often numerous versions for a single domain);

- recalling the existence of existing IFC classes from which new classes could usefully be derived;
- proposing a list of infrastructure components or standard infrastructures grouped by major characteristics that could usefully be the subject of new IFC developments;
- ranking these components or standards according to their apparent economic interest and difficulties for end users.

2.4 UC4 – Project review

2.4.1 Overview of UC4 objectives

During various exchanges with construction industry actors, this working group observed a significant disparity in terms of motivation, understanding, acceptance and maturity with regard to digital technology and innovations, as well as the contributions and changes they could generate.

Use case 4, entitled "Project review", brought together 16 partners. These representatives of actors in the sector shared a view of how to run a project review based on the various disciplines involved in an infrastructure construction project at the different milestones of the project lifecycle.

All the elements, which are presented in the UC4 phase 1 deliverable, start from the assumption that a **BIM is used as a support for the project review**.

During projects, the project reviews are special milestones for the actors to compare views among themselves. They are essentially the point at which the validity and pertinence of the design and construction solutions are confirmed. The existence of a BIM (Building Information Modelling) process and information model providing a visual representation of the construction represents a tool with great potential in this context, and one that requires detailed examination.

2.4.2 Outcomes of phase 1

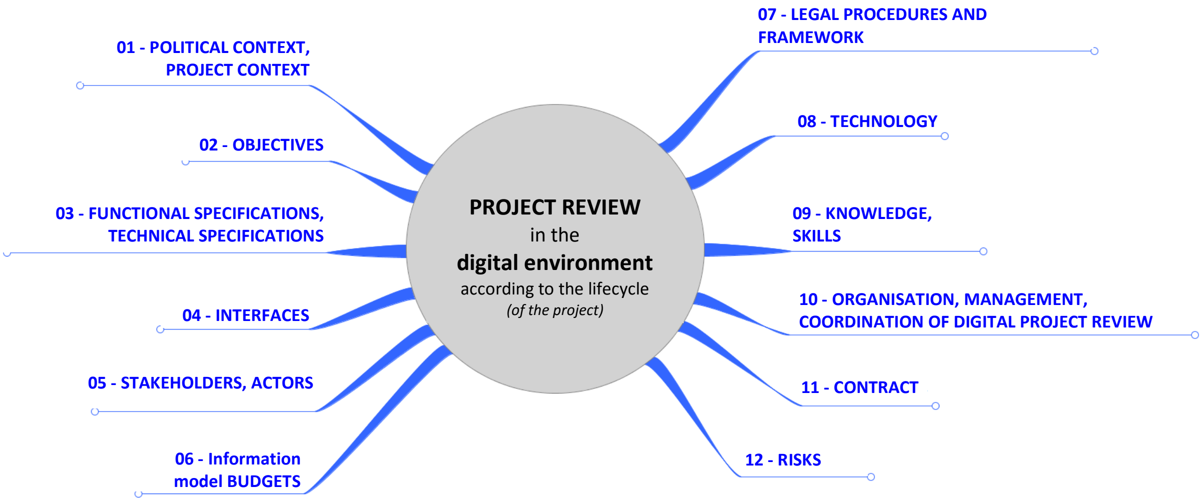
The phase 1 report firstly provides an explanation of the various notions that need to be understood for a successful project review, such as project management, collaborative work and interoperability. After the initial stage to establish and define of the planned work programme, the method used involved checking that a certain shared language could be established among the partners. From this starting point, the partners expressed their expectations, drew up definitions for deliverables and structured the team into a certain number of sub-groups.

The reviews of the state of the art, regulations, and best and worst practices from certain ongoing or finalised projects were presented from different angles. The study gave rise to the observation that there is an infinitely diverse range of situations. However, it also showed that we are far from having found, at this point, solutions that are completely sound and reliable. Indeed, the study showed that the **necessarily cooperative character created by the reference models requires the revision of practices**, new forms of contractual regulation, the participation of all actors from the Project Owner down, and a clear definition of the desired objectives when an information model and BIM process are introduced.

A mind map aided comprehension of the various angles of approach adopted in order to structure the general discussion. The work largely drew on concepts from the field of systems engineering that had been tried and tested in other industries. The salient points of the analysis include the advantages of establishing approaches as early as possible in a project, ensuring that all points of view are present at all times, and carrying out regular reviews to check, as part of a planned, iterative and progressive process, that requirements are being satisfied.

This phase 1 work dealt with:

- the contexts, of all types, in which any information project review takes place, and the possible objectives;
- functions;
- interfaces;
- the stakeholders in the project review, or the points of view that should be represented in the event that the stakeholders have not yet been designated;
- the costs associated with the project review;
- legal procedures and frameworks;
- technological provisions;
- the necessary skills;
- the organisation of resources and the way in which project reviews are managed and coordinated in a digital context;
- the demands that should be dealt with in contractual provisions;
- the risks associated with introducing a digital project review.



This use case has contributed to the various themes of the MIN^{n}D national project:

- the Observatory, as the glossary and reviews of the state of the art are relevant to monitoring as well as internal MIN^{n}D synthesis;
- needs in terms of tools, technologies and process development, which have been identified throughout the work;
- the outcomes should provide a framework for any experimentation in a later phase;
- the scheduling of project reviews leads to the establishment of data structuring systems and process progression rules;

- validation and comparison during project reviews is directly linked to the contractual conditions that should define the liability context in which they apply.

The phase 1 report is a first appraisal of the work and a prerequisite for the drafting of a methodological guide for project reviews.

2.5 UC5 – Cost control through modelling

2.5.1 Overview of UC5 objectives

The various exchanges with the actors involved in a BIM supported infrastructure project (engineering specialists, contractors, operators, publishers, surveyors, economists, project owners) have shown a significant disparity in terms of motivation, understanding, acceptance and maturity with regard to digital techniques and innovations, as well as the contributions and changes they could generate.

Use case 5, entitled "Cost control through modelling", brought together eight partners. These representatives of actors in the sector shared their standard practices for estimating, costing, monitoring and running an infrastructure project from a financial point of view.

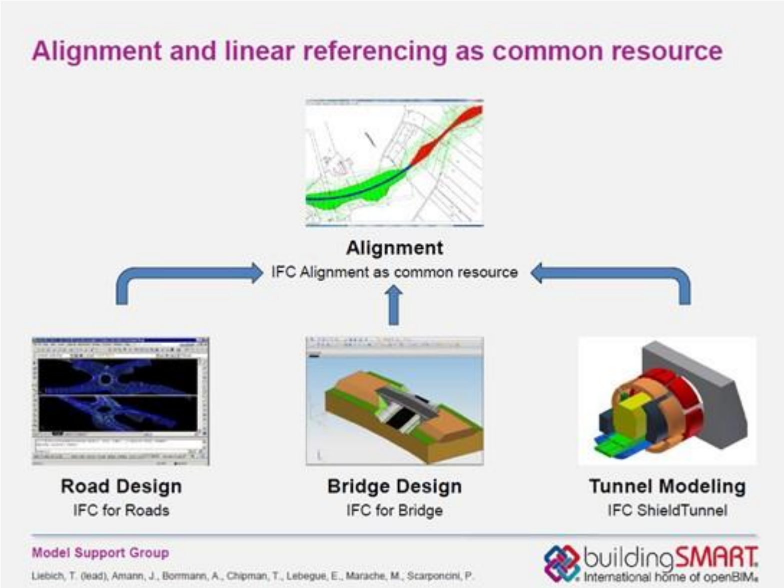
The objective set by the working group was to understand **how BIM will be able to model and manage the total cost of an infrastructure during the various phases of a project:**

1. Estimates, price studies
2. Cost monitoring during the construction phases
3. Cost monitoring during the operating and maintenance phase

All the elements, which are presented in the UC5 phase 1 deliverable, start from the assumption that a BIM forms the backbone of data exchanges between the various parties involved and the project phase.

Four reports have been drafted as part of phase 1. They present a map of the various parties, the most common financial organisation structure for the design/construction phase, the contractual interactions arising from a law or contract, and the tools available on the market to meet the needs of this phase.

A review of the state of the art summarised the lessons learned as regards the development of IFC alignments, Levels of Development (LOD), standards already in existence or under development, and research on price bases. Although IFCs have already existed for several years in the fields of buildings and bridges (the initial version, which remains incomplete, dates from 2004), the extension *IFC alignment* are still being developed. In phase 1, it was not possible to analyse the new standard BIMetre for the exchange of quantity surveying information, which was identified as being in the draft stage.



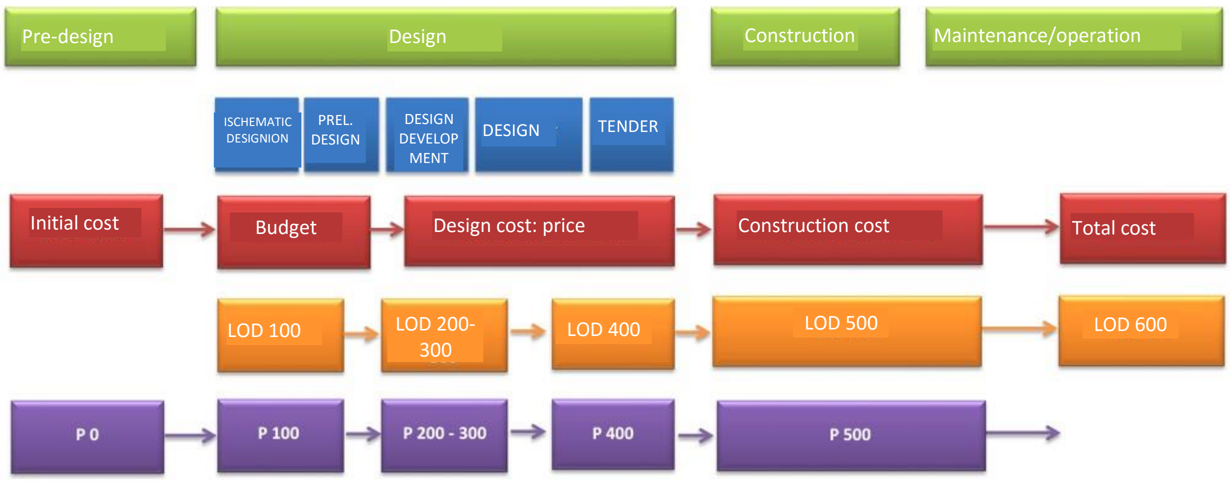
2.5.2 Design phase

The costs and the way in which they are applied and evaluated during the design phase can be used to evaluate and control the project as a whole (total budget) and in detail: takeoffs/quantity/costs, catalogue/unit price. The information model must integrate the notion of total cost in order to obtain a financial view of a project across its whole lifecycle.

A list of elements that may be included in the cost has been drawn up. These elements are generally integrated into an article database or price catalogue. This database makes it possible to cover/rank the prices and make a link to the information model (notion of linking to the article code). Several questions arise from this:

- Should this price catalogue be standardised?
- Should this price catalogue be integrated into the information model or made external?
- Can the price catalogue change according to the design phase (initiation/preliminary design/basic design/design, etc.)?

Different levels of detail and terminology could be envisaged depending on the advancement of the operation, for example "Level of Price" (LOP): notion of level of price or cost on the same principle as the "Levels of Development" (LOD) in the information model (example: LOD 100 –> P 100/LOD 200 –> P 200/etc.), as shown in the figure below.



As for the LODs in a BIM, the costs and prices do not have the same degree of precision as would be contained in these LOPs:

- Estimates, a range
- Ratios
- Calculated prices
- Sub-contracted prices (therefore from a contract)
- Replacement, maintenance and/or operating prices

After that, the LOPs are not linked to the LOD and their definition requires development in phase 2.

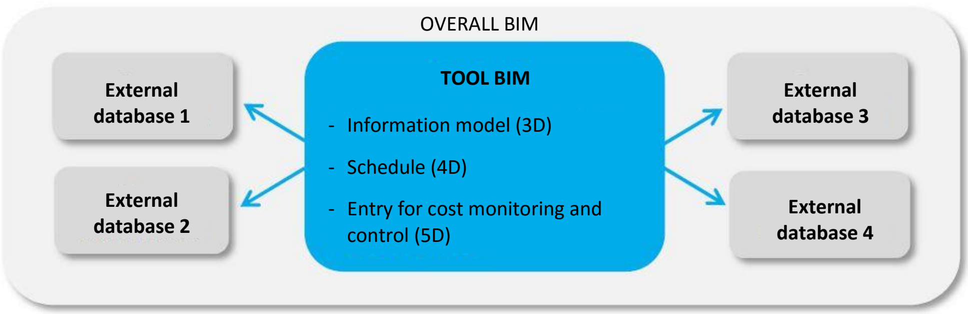
2.5.3 Construction phase

The discussions on the construction phase concerned the budget monitoring for a project, and how exchanges could be digitised.

Different levels of detail and terminology could be envisaged depending on the advancement of the operation, for example LOP: notion of level of price or cost in relation to the LOD in the information model (example: LOD 100 –> P 100/LOD 200 –> P 200/etc.).

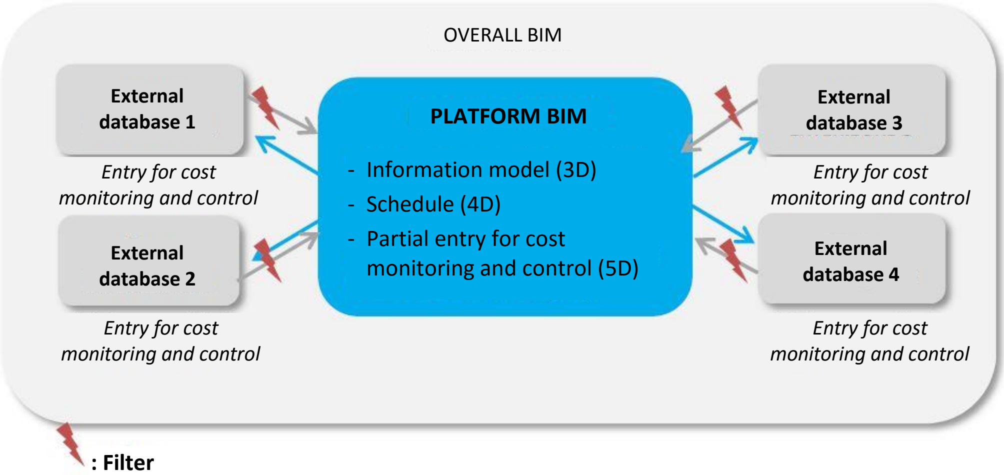
It is easy to envisage two main types of BIM at this stage:

- A "tool" BIM in which all the data would be entered within the BIM; here we are talking about data leading to 5D. In this case, the BIM Manager has an overview of all the data. This tool BIM has a clearly defined scope and may be applied within a company/business/consortium;



- A "platform" BIM to which databases are linked. On an external database it would therefore be possible to find the following information:
    - daily entry of advancement of work;
    - unit prices of company X;
    - organisation of checks, etc.

  Each company would thereby retain the ability to make this information visible or not on the BIM and to the BIM Manager via filters.



This platform BIM would be applied where data is being shared (contractual notion) between different parties/companies.

For the purposes of budget control, a template known by all the actors involved in cost control must be put in place before or at the very beginning of the work. This template will tell the actors (the providers of information for budget control) what kind of information to submit, the desired frequency and the methods to use (tools, transmission circuits with validation, etc.). The template will comprise the following elements:

- definition of the geographical or functional subdivision of the project;
- cost database;
- organisation of entry and validation processes;
- schedule.

2.5.4 Operating and maintenance phase

The discussions on this phase concerned the financial information fed back during the operating and maintenance phase that can be structured using a BIM organisation system.

The aim of the operator is to ensure that the approach taken by the designers/contractors incorporates, upstream, the operator's own needs in terms of data format/attributes, and in terms of architecture.

The phase 1 work identifies the various stages of the lifecycle during which the operator interferes with the BIM and, for each stage, which data the operator needs and how urgently:

- Necessary attributes/what should be digitised?
- Static data ("as-built" inventory) and variable data (state of assets, record of inspections and maintenance operations)

- Which filters?

It pragmatically analyses the architectures proposed for the BIM platform as regards the Asset Management application, proposes areas for discussion on the development of the information model and identifies the principle challenges to be overcome to retain the advantages of the information model in the long run..

2.6 UC6 – Infrastructure and environment

2.6.1 UC6 objectives in phase 1

Use case 6 studies the special case of interactions between infrastructures and their environments at different stages of a project. The objective is to examine how these studies could incorporate BIM.

During phase 1, two cases were considered:

- studies linked to noise, in particular the case in which a noise barrier is built together with an infrastructure;
- studies relating to wildlife crossings and compensatory measures linked to the existence or construction of an infrastructure.

By studying these special cases, the aim was to better understand practices, the use of data and the difficulties of using 3D data.

The work in phase 1 demonstrated that there is **major specialisation in terms of skills** and actors on the one hand, and **that there is a great deal of complexity in the use of data and software** on the other. As each project involves a large number of tasks, actors are specialised in particular domains (see report UC6.1 on noise, for example). Modernising by shifting towards the use of digital data does not therefore require a single element to be changed, but rather a collection of software, processes and methods. The software used is often multifunctional, and learning how to use it is no trivial matter. The most acute problem is surely the fact that the digital data describing infrastructures are not seen as databases but as the internal elements of proprietary software, which does not facilitate their interoperability.

The reports written by the UC6 group in phase 1 introduce elements that show the complexity of the processes, software, actors and exchanges. Given the specialisation in terms of skills, it was not possible to obtain, as we would have liked, information on the use of 3D digital data for wildlife crossings or on the archiving of data, which are two points we consider essential for the future. These studies will form the subject of phase 2.

2.6.2 Infrastructures and noise

The acoustic study looked at the **flow of the data** required for the acoustic study from the point at which they enter the discipline process to the production of deliverables (the handeled objects only, and not the reports, for example); the technical outputs of the acoustic study should usually enter the project database (electronic document management system).

Input barriers have been identified:

- in data relating to surveys of existing elements;
- in outputs from other disciplines that feed into the acoustic study model;
- in the acoustic discipline tool in the integration of input data (data re-entry and transformation, etc.).

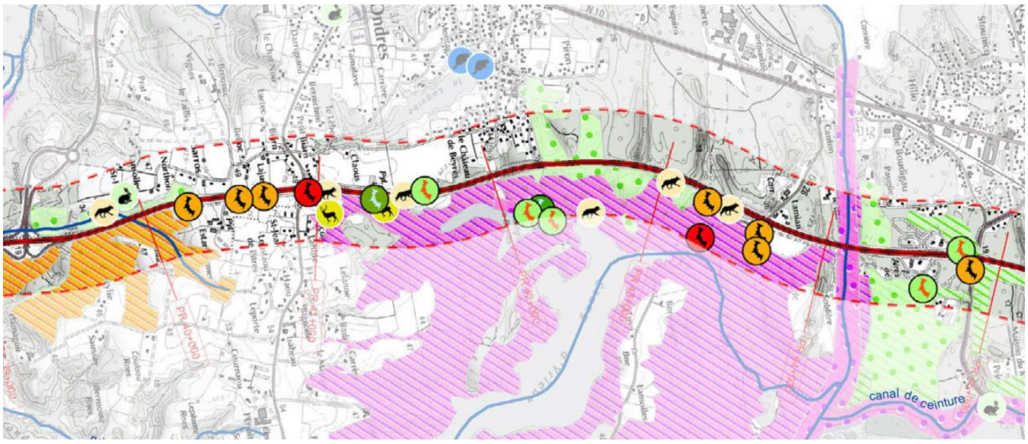
Output barriers:

- limited export formats;
- no possibility of connection to an electronic document management system.

It should be noted that it is possible to use the open format CityGML in a CadnaA model, but this requires improvement to allow recognition of the different classes of object, and attributes, and prevent modelling of all the objects in a single object class. It would also be helpful to check that CityGML (with noise ADE extensions) is sufficient for exchanging the objects that come up in acoustic studies.

2.6.3 Infrastructures and environmental transparency

This action dealt with the challenge of **monitoring environmental measures implemented to reduce and compensate for the environmental impacts of linear infrastructures, from the point of view of data exchange and information monitoring**. The involvement of various types of actor in the generation and use of the data was also examined.



The use case is a section of highway undergoing widening and/or environmental requalification with the construction of a wildlife crossing (impact reduction measures) and compensatory measures. A distinction was drawn between two cases:

- that in which a wildlife crossing is built;
- that in which a highway is built without a wildlife crossing but where compensatory measures are required.

The work made it possible to identify, by differentiating between what already exists and what we wish to obtain through well-structured, comprehensive and accessible digital data:

- **the data to be taken into account** throughout the construction of a wildlife crossing. The actors concerned were also identified;
- **the interfaces** between infrastructure data and other data;
- **the indicators** (referred to as metrics) that enable characterisation of the environment around infrastructures to monitor the impact of the infrastructure on the environment;
- **the compensatory measures**: the issue of calculating the compensatory measures and checking their effectiveness over time is addressed, with the analyses relying on the existence of digital data.

The issues regarding archiving were also tackled with the aim of responding to the following question: What should be retained and how in order to most effectively manage the infrastructure interactions over time?

The role of simulations in deciding where wildlife crossings should be located was also examined. Currently, location decisions are not based on simulations as is the case for noise protection measures. Areas for progress in this area have been presented. They concern digital data that describe the environment, infrastructures and transitions.

This work makes it possible to establish the bases for phase 2 of MIN^{n}D, which will use data and software to perform a concrete analysis of the interoperability challenges for data and software in designing the construction of a wildlife crossing on an infrastructure, based on the environmental resources and data archiving that would be required. The general conclusion will therefore be presented in phase 2.

3 Themes in phase 1

Two themes were active during phase 1:

- Theme 0 - Observatory, notably through the organisation of MIN^{n}D campus seminars
- Theme 4 - Proposals to adapt the regulations

Themes 1 to 3 were not formally studied in phase 1 as the associated working groups have not been set up, and they are not the subject of any deliverables as yet. They will be studied in phase 2, which aims to initiate the transition from work based on use cases to work based on themes, although the two are not mutually exclusive as the use cases feed into the discussions on the research themes.

3.1 Theme 0 – Observatory

A working group met during phase 1 to lead a review of the state of the art and exploratory work regarding what a BIM observatory in the sector could do. Various observatories were analysed and interviews carried out.

Two main types of observatory were distinguished, although they are not mutually exclusive:

- those centred on the organisation of multiple data;
- those centred on skills and disciplines.

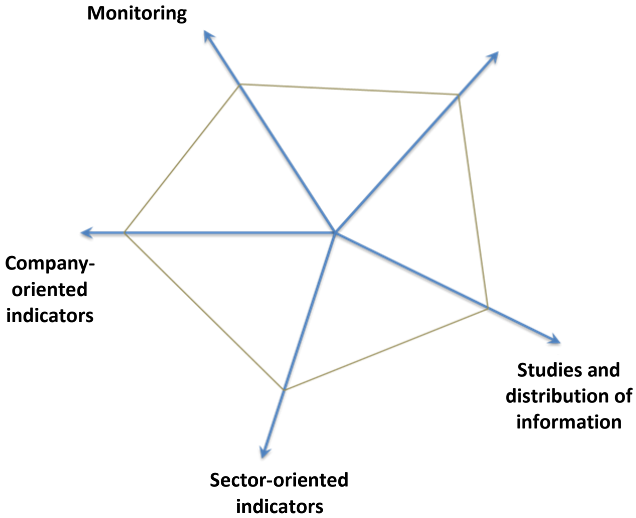
There are two types of function:

- studies, in particular prospective studies;
- exchanges between practitioners and analysis via changes in practice, and transformations linked to BIM in the sector.

The primary role of an observatory is to gather data (Miralles, 2015), but this has evolved from strict observation and description, and now covers the field of information systems and extends as far as decision support systems and governance support. Overall, the functions of observatories are focused on knowledge: its acquisition, retention, modelling and forecasting. They are almost always oriented towards collaborative activities based on this knowledge and data.

A second major orientation for an observatory is skills and disciplines, in which case the observatory generally has a joint function (we consider the French metallurgy observatory UIMM a prime example of this). Skills are a good way of describing a sector, including technological developments, as changes in skills are a good indicator of technological changes and the way in which disciplines are evolving. We might say that entry by the skills for a sector is unavoidable, even if it is not the only possibility.

Observatory composition scenarios can be developed based on the major functions we wish to prioritise. For example, in the areas comprising the major functions of the observatory, we must decide where we allocate strengths and how we prioritise certain functions.

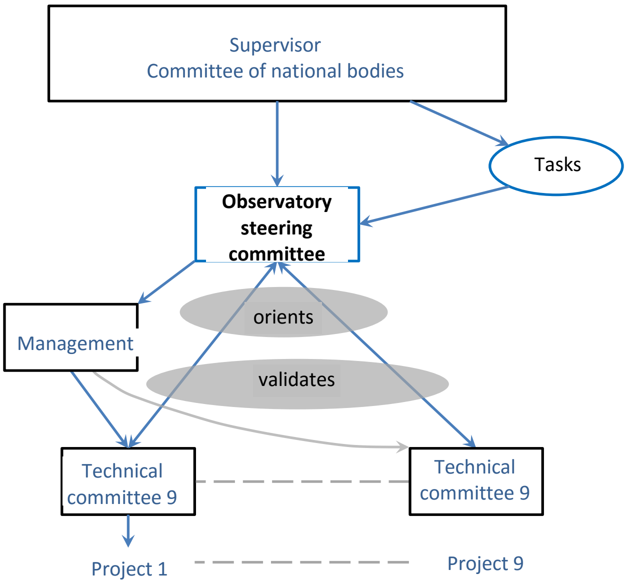


The sudden breakthrough that BIM represents is taking place via a profound modification of design tools, but it is also introducing collective engineering and collaborative work engineering. Beyond the software tools at the centre of the change, it is the organisational practices and processes that are affected. How can these changes be observed? The fact of wanting to observe a changing phenomenon undergoing extremely rapid, and frankly unpredictable, development involves examining specific and extremely heterogeneous data. These data simultaneously concern software, organisational processes, professional practices, developments in knowledge and skills, and the rebuilding of disciplines. The ambition of the observatory is not only to assist companies with self-assessment in relation to this technological breakthrough (hence the work on indicators), but also to help the sector evaluate the development of the sector.

3.1.1 Observatory diagram

The structure could be very light, with a strong management capable of gathering experts on an ad-hoc basis, encouraging them to work jointly and combining aims, but also able to resist the pressures of the sector. This means that there would be coordination functions in addition to management functions, combined with a capacity to provide meaning: relevance and an astute vision must inform orientations.

The organisational structure for the observatory (inspired by that of UIMM) that seems most suited to the objectives of MIN^{n}D is summarised in the conceptual diagram below. The observatory would receive its tasks from a representative national council drawn from the sector that would constitute a national body.



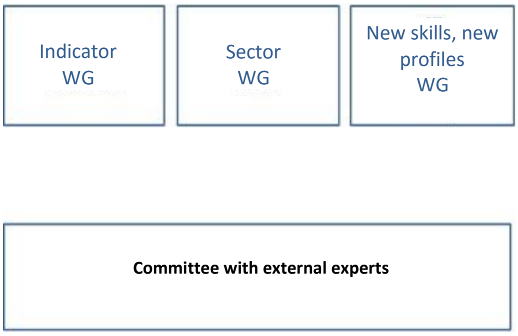
The observatory steering committee would provide guidelines and validate the creation of projects. For an observatory to function, this steering committee would have to be political, meeting around five times a year. It would have a limited number of members, no more than 20; at UIMM there are 10 union representatives and 10 company representatives. Each project would concern a specific, carefully chosen theme and be led by a technical committee.

It is therefore possible to start drawing up a roadmap for phase 2 with a view to working towards an observatory and setting up certain elements of the observatory on an experimental basis during phases 2 and 3 of the MIN^{n}D.

Three working groups are envisaged:

- One on **the indicators** to generate proposals for indicators, starting by evaluating those offered on the market and proposing a specific evaluation grid for the various indicators available. This group would generally be oriented towards self-assessment for companies.
- A second working group oriented more towards **the sector**, and with a focus on **monitoring**. Beyond monitoring, this group could take up the idea of mapping based on families of disciplines.
- A third working group to explore **the new profiles and new skills that BIM requires**. This is a specific request from educators that was expressed during the EDUBIM 2015 meetings (Bagieu, 2015). It is a response that the sector should be able to formulate, above all for itself. What are the consequences of BIM for the sector in terms of skills: what precise needs will there be for new skills? How do these skills form new profiles? How do we train these new profiles? Through both initial training and continuing training; we are talking here about work that can only be done in cooperation with the educators and trainers involved in continuing training.

A scientific committee for the observatory, comprising several experts from outside the sector, would help the MIN^{n}D project refine its observatory proposal for the sector and ensure coordination of the three working groups as shown in the diagram below.



3.1.2 MIN^{n}D campus seminars

The aim of the seminars is to offer **external input of very high quality** that makes it possible to step back and gain perspective on a specific BIM theme, and thereby inform thinking and discussion within the project.

Eight seminars entitled "MIN^{n}D campus", **open to the whole community affected by and with an interest in BIM**, were organised regularly during phase 1 of the project:

Seminar 1 - Information systems and design	Complex systems engineering today relies on a set of information models that generally have to coexist within a multi-discipline design process. These models, extremely rich in certain cases, do not however cover all the knowledge relating to the overall lifecycle of the system and to the design decisions. This seminar looked at the way in which these deficiencies could be remedied by working on process models, as well as the interoperable grouping of knowledge models in order to make the information system flexible in the face of a changing industrial context. *Speakers: Lionel Roucoules (ENSAM) and Christophe Castaing (Egis)*
Seminar 2 - Law and information models	Collaboration with collaborative tools should promote productivity for all partners: engineers and contractors. It should enable innovation (variations) without diluting responsibility. As the notion of data evolves, provision should be made for the evolution of contract law, and this will be based on data law. The question raised by this seminar was: how can data assure the full traceability that is becoming necessary? In particular, how can we ensure consistency between the three necessary layers: the programme, the presentation and the technical specifications? *Speakers: Danièle Boursier (CERSA) and Christophe Mérienne (Egis)*
Seminar 3 - Point of view from professional organisations	Amid all the national and international BIM initiatives, the directors of our major professional organisations have spoken out about the strategic issues regarding BIM that they associate with this movement, and the reasons why they deem it necessary to accompany it with a decisive research effort.

	Speakers: Pascal LEMOINE (FNTP), Patrick Duchateau (FFB) and Christophe Longepierre (Syntec Ingénierie)
Seminar 4 - Collaborative design	Flore Barcellini from CNAM presented the forefront of developments in cognitive ergonomics in the field of collaborative design and support activities. *Speaker: Flore Barcellini (CNAM)*
Seminar 5 - Constructing ontologies: the example of medicine and the resulting good principles	Based on more than 20 years' experience in the medical domain, Jean Charlet from AP-HP and Inserm has demonstrated the difficulties of developing ontologies for support information systems and the various traps that can be encountered. *Speaker: Jean Charlet (AP-HP and Inserm)*
Seminar 6 - Who will lead the breakthrough?	By asking who should lead the breakthrough, Philippe Silberzahn from EM Lyon invited us to reflect on the evolution of business models during breakthroughs and the ever-increasing appropriation of value through software. *Speaker: Philippe Silberzahn (EM Lyon)*
Seminar 7 - Presentation of Medi@Construct advances	Medi@Construct has set up a working group, representing professionals and their organisations, in order to draw up a BIM execution plan in support of design or execution contracts. This group introduced its work at various committees of the PTNB (French digital transition plan for the building industry) a few weeks ago. Jean-Paul Trehen, who chaired this working group, presented the "BIM execution plan" and "Glossary" projects and gave an update on the follow-up to this work. *Speaker: Jean-Paul Trehen (Medi@Construct)*
Seminar 8 - Presentation from AFNET/BoostAeroSpace European aerospace hub	Developments in the use of BIM, modelling and processes in the construction industry will be an integral part of developments in collaborative and collective work. They will therefore certainly rely on the development of tools to facilitate this work, such as have already been put in place in other industrial sectors. Pierre Faure gave a presentation on AFNET and the BoostAeroSpace European aerospace hub, a collaborative platform offering high-security collaboration services in the field of design and procurement. *Speaker: Pierre Faure (AFNET)*

3.2 Theme 4 – Legal and contractual aspects

3.2.1 Overview of theme 4 objectives

Entitled "Proposals to adapt the regulations", theme 4 aimed to study the legal issues associated with adopting BIM in construction projects, and draw conclusions from this regarding contractual relations and intellectual property.

Based on the possibilities offered, as well as the technical constraints imposed by the BIM tools (software, formats, platforms), we proposed covering:

- The definition of data access rights
- Modification management
- Information approval and validation
- Decision traceability
- The characterisation of intellectual property
- The definition of tasks and associated responsibilities

This notably required a certain number of notions to be defined, whether in regulatory or contractual terms:

- Level of detail or development of the data exchanged
- Integrity of the model
- Necessary richness of the data
- Just sufficient data quality

The expected deliverables include:

- A guide to drafting contracts between stakeholders
- Proposals for changes to legislative and regulatory texts
- Proposals for standard contracts

3.2.2 Phase 1 work and changes in context

On these issues, the working group had to bring together skills from very different disciplines. This was satisfactorily achieved, as specialist BIM practitioners, actors involved in works, engineering specialists, corporate or university lawyers and insurance specialists, among others, participated regularly in the work. The working group also benefited from the invaluable participation of a doctoral student in law who had chosen part of this theme as her thesis subject.

The counterpart for this diversity was that significant time was needed to establish a common field of comprehension of the subjects and issues tackled. However, at the end of this mutual and reciprocal explanation period, everyone had without doubt made progress in their understanding of the multiple dimensions of each subject.

Another challenge was the numerous events external to the MIN^{n}D project that occurred throughout this first year, interfering with the work programme so that it had to be adjusted as we went along:

- the publication of the French Ordonnance of 23 July 2015 and the associated draft decrees transposing the European Directives of February 2014 regarding public procurement, and notably preparing for the dematerialisation of public procurement contracts at all stages.

Uncertainties regarding the schedule and content of the texts being prepared led the working group to suspend its initiative on proposing elements for a potential "guide to public procurement";

- the launch of the French digital transition plan for the building industry (PTNB), led by the Ministry for Housing, in which several working groups looked at subjects close to those implemented as part of MIN^{n}D. In particular, the PTNB's "public project owner" working group proposed drafting a guide for public project owners, largely oriented towards explaining the notions of BIM and highlighting its benefits;
- the provisional distribution, at the end of 2015, of the "BIM execution plan", prepared by a Medi@Construct working group. This guide was intended for the construction industry, and did not include proposals for a "standard contract";
- various other initiatives also marked this period. While this demonstrated the importance of these subjects and scale of current deficiencies, they were often launched without real care being taken to ensuring consistency across all actions.

As a consequence, the theme 4 working group had to monitor these initiatives and adjust its programme as much as possible to avoid duplicating work, and above all to prevent any unjustified inconsistencies that could arise as a result.

It was however possible to take some first steps, leading to the production of intermediate deliverables, which will require reviewing and revising throughout the project:

- a study on the **contractual framework** into which the BIM process should fit;
- a first document on the **relationship between BIM and public procurement**, on the one hand, and **the notions and issues surrounding intellectual property** as applied to copyright, data and databases, on the other;
- an analysis and summary note on the **tasks, associated responsibilities and consequences regarding insurance**.

4 Transfer and promotion

4.1 EDUBIM 2015

On 16 and 17 June 2015, **BIM specialists involved in education** met at the ESITC Caen, a construction engineering school, as part of the MIN^{n}D project. The participants found the two days both exciting and productive. The meeting brought together almost 200 participants, with a high turnout from MIN^{n}D partners, who also contributed to the conferences and round tables. ESITC Caen is at the forefront of this subject, as teaching on BIM is included in all course subjects and modules. The event was unique in that it united a wide range of professionals from companies: large groups and SMEs in the construction sector, several software publishers and a broad selection of educators from vocational colleges and engineering schools, both public and private. This great diversity of viewpoints made it possible to work on course content and teaching methods for developing, whether as part of initial or continuing training, the profiles and skills that the construction industry now needs to manage this technological breakthrough. Bertrand Delcambre attended to participate in the work and close the sessions.

The success of the meeting was important to show the value of discussions for all parties. What were the other outcomes of this MIN^{n}D initiative?

- The establishment of a network of BIM educators is already a result in itself.

- The fact that this network generates instant interaction between companies and a research project is an advantage for both this network and the MIN^{n}D project.
- The interactions between the MIN^{n}D project and the education network are well-established and working groups can be envisaged as a result.
- The remarkable interaction between companies and educators shows that further exchanges and joint work can take place.

The presentation support documents from the EDUBIM 2015 days can be downloaded at this link: http://www.minnd.fr/edubim/edubim-2015/

4.2 Promotional activities

The main promotional activities undertaken during phase 1 included:

- the organisation of "MIN^{n}D campus" seminars open to the whole community affected by and with an interest in MIN^{n}D;
- the presentation of the programme at national, and even international, conferences;
- the presentation of the programme in specialist reviews, with one example being the "Travaux" review (a French technical review for companies in the public works sector), edition 917 (BIM special);
- the construction and maintenance of a website (www.minnd.fr), which notably includes a "news" section.