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TOWARD NON MATURE INFORMATION MANAGEMENT IN COLLABORATIVE DESIGN PROCESSES

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1. Introduction

The organisation of collaborative design activities requires, at the earliest stage of the design, a definition of mechanisms which allows an exchange of evolutional and *non-mature information*. Whenever the information is not validated, Engineers have to make decisions about the product, managing uncertainty with scenarios, hypothesis etc. This is especially accurate in the early design phase of large scale one-off products as hydraulic power station. The actual computing systems, in particular those intended to manage technical data, are hard to conciliate with this dynamic and evolutionary aspect of the design data. It results in relatively static systems in which data is partially integrated, such as CAD model, which represent fixed and valid states. This article is based on qualitative study of the hydraulic energy and civil engineering design process. The main characteristics of the collaborative design situations are highlighted. Based on these features, a framework for managing the *non mature information* within collaborative *working spaces* design process is introduced.

2. Design information in collaborative activities.

2.1 Open and Closed intermediary objects

Previous accounts of design work point to various ways in which design works depends on communicative activity [1]. Design work is related to the production and the use of information. Information produced by the actors of the design is rather heterogeneous. This communicative activity is supported by many artefacts all along the design process. We use the notion of *Intermediary Objects* (IO) [2] to describe the objects that appear or that are used in the process. It could be as well digital models, drafts, tables of data, as plans or prototypes, etc. whatever their form, their origin or their destination: schedules, minutes, functional graphs, calculation results, drafts, 2D plans or 3D models, prototypes, etc.

Those IO can be seen as results from the design work but also as supporting and highlighting it. The Intermediary Object enables us to raise general questions about how the design processes under study actually function. This is due to the hybrid character of the IO in modelling the future product, those objects act as communicating vectors between the product designers. These two aspects are so much connected in the reality of the process that we cannot isolate one from the other without deforming their nature. As a vector of communication, the objects structure the design network. Like models of the future product, they highlight its evolution.

All the intermediary objects do not have the same characteristics in the design. Those characteristics depend on the properties of the object itself and on the situation of action in which it is committed. Observers of design activity have highlighted the “mixed-use practices” [3] [4] of designers combining the electronic and paper world. Depending on the margin that is left to the user, we identify open or closed objects. A closed object transmits a strong regulation, whereas an open object is a support for negotiation. Deliverables produced for project miles stones are closed objects. The *draft*, the *exhibit* and the *enabled trace* (§2.2) are open intermediary objects support negotiation and the emergence of the solutions. The position of an object on this axis depends on the statute of the information given by the actor, and on the object itself. In the concurrent Engineering processes the role of open intermediary object is increased.

2.2 Intermediary objects evolution

In order to understand the intermediary objects evolution within design projects, it is important to observe the designers practices. Several authors [5] [6] [4] have highlighted that to publish information requires commitment from the publisher to the other actors (hierarchy, colleagues….).

Lécaille [4] focuses on the evolution of a type of intermediary objects: the *digigraphics* during design according to three action modalities:

- *Draft*: «It is an object that one has to apply the modalities of creation and validation of hypothesis or solutions to a project or to a design problem. They are defined by a design actor individually”.

- *Exhibit*: « objects that one applies a persuasion modality in accordance with what is represented in either for convincing about the existence of a problem or for showing a solution and allowing a common construction and the point of view exchanged ».

- *Enabled trace*: « objects that the designer accepts to diffuse to others, after his consent or his agreement with a collective prescription to which he takes part. It is non-officially validated objects but sufficiently convincing to be published».

In addition to these states, our study considers the deliverable objects as mentioned in (§1).

- *Deliverable*: Objects that transmit a strong regulation. They have been formally verified and validated (by hierarchy). Deliverable are those contractual supports to being communicated to the client.

Some[1] intermediary objects evolve from open (draft, exhibit and enabled) to closed states (deliverable) within the design process (§4.1). Their publication is a process that involves social aspects that the information management system has to take into account. We argue that the collaborative support systems should support the evolution of the information within specific *working spaces* (cf. §4.1). The designer is committed by the information he delivers to other actors. He could not diffuse *drafts* within any design working spaces. Actors take care of what information they diffuse in design team. This caution sometimes delays the disposal of information for the others. The information exists but is not accessible. We argue

[1] Not all the intermediary objects become deliverables. In that case, they are used in order to fulfil a given need in design.

that it is possible to spread immature information earlier if we allow the providers to *characterize its maturity*.

2.3 Maturity of the information

The intermediary objects exchanged by the actors of the design are heterogeneous in term of the *maturity*. In a plant technical draw, for example, some information of design are the results of decisions, some are only hypotheses. Some data are frozen and stable, others are uncertain and non reliable. The information that actors need to carry out their tasks is sometimes not available. In that case they have three options according to Terwiesch [7]:

- The first option is to wait then the project risks to delay because of *starvation*[2].

- The second option is to make hypothesis about the value of the missing data: the risk in this case is rework and design iteration. The quality of the task results depends on the reliability of their hypotheses.

- Third is to manage alternatives simultaneously. Disadvantage is that the solution is expensive.

Many authors were interested in the maturity of the information in projects. Terwiesch [7] explains that the co-ordination strategy should be chosen by the knowledge of the *precision* and the *stability* of *preliminary information*. Yassine and al [8] propose a structural model SSA (Structural Sensitivity Analysis) based on DSM (Design Structural Matrix). They introduce the concept of *dependency strength* between tasks. It results from the multiplication of the downstream *sensitivity* and the upstream *variation* measures on exchanged information. According to the dependency strength value, a risk management strategy is applied [9], [10] and [11]. Crossland [12] defines design information in early design process as abstract, uncertain or incomplete information. One of the aims of her studies is to obtain early estimates of the costs, performance parameters, time-scales or other design attributes in order to better manage the risks in design. Several other authors use different criteria to express the maturity of design information: certainty, precision [13], completeness [14] and ambiguity [7], etc. In companies, design actors use some criteria to express the maturity of the information, usually in form of comments diffused by e-mail or phone that accompany the intermediary object itself. But these criteria are not consensual within the company. Below, we propose to measure the *maturity* of the design information as a set of some criteria: certainty, stability, precision, completeness and information updating inspired by both literature and field studies.

- Certainty: *« uncertainty occurs in engineering design, in the form of manufacturing variations, material property variations, etc»* [13]

- Precision: *«accuracy of a piece of information. Its measurement can be derived by comparing the range of outcomes that are communicated with the range of all possible outcomes (for discrete sets), or by comparing the range of communicated outcomes to the distance of the range from zero (for parameter intervals) »* [7].

- Stability: *« the likelihood of the piece of information of no longer being modified through the remainder of the process»* [7].

[2] Corresponding to design sticking situations.

- Updating: *« the date of the last change ».*

- Completeness: *«indicates the objectives to comply with, it's the structure of the future information…. Objective has to be defined and need to be stable, it expresses the needs»* [14].

Those criteria have to be adapted to the company's culture. The aim of the paper is not to discuss the choice of the maturity criteria but we will use them in the models below as example. Further studies will be conducted in the future in order to analyse and compare the different criteria of maturity used in the literature as well as in field studies.

We call 'characterization of information' the action done by the provider to value those criteria for information he spreads.

The present work is illustrated by concrete situations of design solution elaboration. Designers use and produce different intermediary objects. As is shown above, some of these objects evolve during design. Those are objects exchanged between designers in collaborative activities. In the section (§3) below, a description of some collaborative activities and their relating exchanged and evolved intermediary objects, is done.

3. Case study

As a case study, we investigated the civil engineering design process in a *Hydraulic Energy and Civil Engineering Design Office* (HECEDO), where the design process involves numerous tasks and collaborative activities. The product under consideration consists of a hydraulic structure, which has the dam, power plant station etc. as its constituents. The project concerns the implementation of new hydraulic structures (dam, power plant stations…) as well as the maintenance of existing ones.

The analysis of the design process at HECEDO was performed over four months during which the author stayed on site full-time. We were partly inspired by the Action Research approach [15], consisting of data gathering, data feedback, data analysis, action planning, implementation and evaluation. Section (§3.2) and (§3.3) below summarize the main results obtained from the research methodology step.

3.1 Design Process at HECEDO

The HECEDO design process is formalised in three main sub-processes: contractualisation, study, and realisation. In this paper, we are interested on the second one (study), which can be decomposed into the next *phases*: pre-feasibility, feasibility, basic design, and detailed design. The Figure1 corresponds to UML [16] representation of this design process. The decomposition is applied as follows: a design process is finished by a decision activity, which may decide to interrupt the design process or to continue on it, passing to the next process. An elementary process is called a *phase*. A phase produces and uses *deliverables* (cf. §2.1) corresponding to a set of stabilised information represented in *closed intermediary objects*: plan, CAD model, technical report…etc.

As an illustration we consider the feasibility phase. It produces: outline drawings, plant transversal section, technical reports …etc as the "output" deliverables and uses: contract specification, topographical database, geological data…etc as the "input" deliverables.

Our observation highlight the fact that when the elaboration of the design solution is underway, design actors use and produce open intermediary object to represent their ideas and rough drafts solutions. As said above (§2.2) once the design solution is validated, the intermediary objects are closed and some of them become deliverables which are recorded in computer system such as EDMS in order to be formally verified and approved.

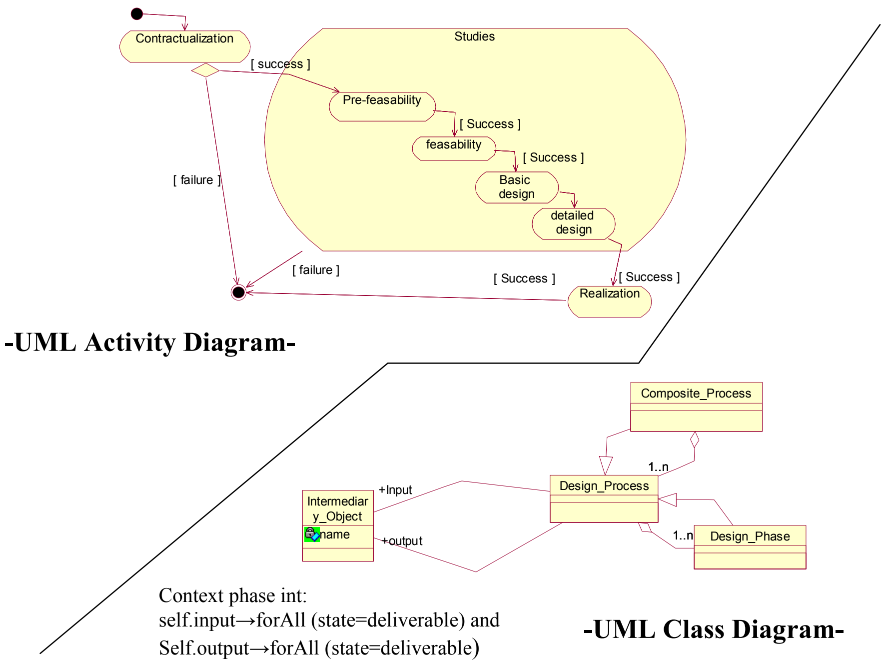


Figure 1 Design process and design phases in HECEDO.

The following paragraph presents research results at HECEDO concerning the description of a design solution elaboration phase. We present a scenario of activities progress related to the elaboration of the technical draw within the feasibility phase of a new design installation.

3.2 A design scenario during feasibility phase at HECEDO

This section focuses on the description of a design scenario performed by civil engineering and mechanical engineering designers. The UML activity diagram of the figure 2 illustrates this description which is done ex-post. This represents non exhaustive and a simplified design situation. Neither activities concurrence nor design iterations are considered in the description. That is for comprehension purpose. Extensive considerations will be exposed in the section (§4).

The feasibility phase is broken down into design activities; each one is performed by one or more design actors: “topographical & geological representation” activity executed by a civil engineering designer, “hydraulic shape calculation” activity executed by hydraulic engineer and “installation dimensions estimation” executed by both civil engineering and mechanical engineering designers, etc.

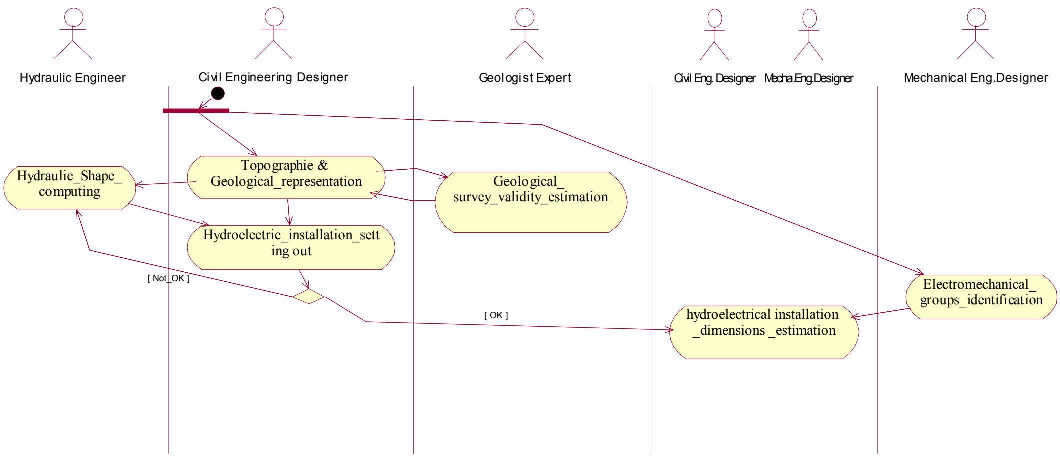


Figure 2 Scenarios of activities for elaborating technical draw.

At the beginning of the project, the civil engineering designer represents the different topographical layouts of the site in form of the *surface model*. For that purpose, he uses topographical map and geological chart which validity may be verified in collaboration with a geological expert[3]. The surface model is then transmitted to the hydraulic engineer. With the combination of the *water precipitation* and other data, the hydraulic engineer may have estimation about the *hydraulic shape* of the site. It is a geometrical file containing information about the natural surface line in terms of *topographical coordinates*, *run-off*[4], *longitudinal bed profile*[5] *and rate of flow*. Once the longitudinal bed profile is estimated by hydraulic engineer, it is transmitted to civil engineering designer who attempts to provide an optimal[6] setting out of the hydroelectric installations: dam, power plant, penstocks[7], etc. based on the topographical and geological data representations of the site. The technical draw of the installation setting out is then transmitted to the mechanical designer who regarding to the *head*[8] value, estimates the installed power plant value, the number of machines per group, etc. Then civil engineering and mechanical designers meet intensively to evaluate the *dimensions of the power plant* and the characteristics of electromechanical machines around and inside the power plant. At the end of this cooperation, designers finalise their technical draws and transmit them to the project team manager in order to be verified and validated.

The table (1) below summarizes the main design activities performed for the elaboration of feasibility plant technical draw. For each activity, one associates the responsible designer(s) and the relating input/output intermediary objects.

The analysis conducted in this section permits to identify relevant characteristics of the design activities and the involved intermediary objects during the elaboration of the design solution. These observations are consistent with related works in the literature [6] [17] [5].

3 This actor may be outside the project team and even external to the considered organisation.
4 Water flowing on or below the land surface under gravitational influence.
5 The profile of the waterbed in the run-off sense.
6 An optimal implantation corresponding to hydro power value.
7 A pipeline or a pressure shaft leading from the headrace or low-pressure tunnel into the turbines.
8 A protection against scour or a protection against erosion.

Table 1. The main design activities, designers and intermediary objects involved in feasibility technical draws.

Activity	Responsible Designer (s)	Input I.Object(s).	Output I.Object(s)
Topographical map and geological chart.	Civil Engineering Designer	Geological chart, topographical map	Surface model
Geological survey validation.	Geologist Expert	Geological chart	Geological chart
Hydraulic shape calculation.	Hydraulic Engineer	Water precipitation, geological chart, topographical map.	Hydraulic shape
Hydro electrical installation setting out	Civil engineering designer	Hydraulic shape, geological chart, topographical map.	Hydro electrical installation setting out technical draw
Installation dimensions estimation.	Civil engineering designer & Mechanical Engineering designer	Hydro electrical installation setting out technical draw, geological chart, topographical map.	Installations definition technical draw.

Hence the focus is put on the intermediary objects that are involved in collaborative activities (objects that appear in both 3rd and 4th column of the table 1). We introduce the concept of *interface information* to refer to these objects.

4. Interface information within collaborative design phase

Intermediary objects are heterogeneous in the sense that they represent both *discipline information* and *interface information* (known as cooperative entities in [18]). *The discipline ones are specific discipline system characteristics corresponding to behaviour of material, parameters, constraints, building code etc*. however, the *Interface information are those destined to be decided and/or negotiated between different designers*[9]. For instance*:* the *rate of flow* in hydraulic shape document is interface information between the hydraulic engineer and the civil engineering designer. Furthermore, the interface information may be the intermediary object globally (topographical or geological models communicated to hydraulic engineer), a "part" of it (power plant and pressure pipe line in the installation implantation drawing communicated to mechanical engineering designer) or even an elementary characteristic [19] of it (rate of flow in hydraulic shape communicated to civil engineering designer).

4.1 Interface information and their evolution within design phase

Both discipline information and interface information have to evolve during the design process. However in this article the authors focus on how the designers collaborate around interface information that are destined to be negotiated between different design actors. During the elaboration of the design solution, the interface information evolve through the four states (draft, exhibit, enabled and deliverable) mentioned in section (§2.2) above.

[9] Designers Belong to the same discipline or to different disciplines but playing different roles in design.

First, the designer produces a *draft* (§2.2) based on information from intermediary objects and on his own knowledge and competences. These information are kept in the *personal* space of the actor (for example designer's desktop for printed objects or his hard disk for numerical data). This is the case of the hydraulic engineer who, before producing the geometrical hydraulic file, produces an Excel file that contains topographical coordinates that are necessary in the natural surface line calculation.

Then the designer needs to confront his ideas with other actor's point of view. This corresponds to a collaborative activity which necessitates the contribution of several design actors who shares the collective knowledge [20]. In this step the collaboration is generally reduced to a *personal network and loyal relationships*. Thus, the designer can expose himself to critics and judgment of others. This collaboration is asked for a specific need and could evolve during the project depending on the competencies of the actors. This is the place of informal confrontation and advice, e.g. the civil engineering designer and the geological expert coordinate in order to verify and validate the geological data. The role of this collaboration is the construction of a robust and convincing discourse to argue the solution. We use the term of *exhibit* (§2.2) to characterize the interface information used in that type of exchange.

When the argumentation is coherent and or when the information is considered to be valid, it can be transmitted outside the *personal networks*. One means by validated information: those information that fulfil their users' requirements concerning either the conditions about the product (the high of the dam should be less then 100 meters) or about meta-information (the precision of the dam high should be about 40%). Thus the design actor spreads the information to the concerned user(s) in the *official* space (the common database or PDM system). We have chosen the *enabled trace* (§2.2) term to name the status of interface information involved in that exchange. That is the case for the hydraulic shape that the hydraulic engineer places in his shared space (profile) in order to permit to the civil engineering designer retrieving it.

The evolution of the information from *draft* to *enabled* states is not linear. In any time of the design, enabled trace or exhibit information could be back to exhibit or draft and vice versa.

Finally the design solution is validated by the hierarchy: project team manager, department manager. Thus, the intermediary objects will be closed and some of them are published as deliverables in the information management systems (PDM systems).

4.2 Collaboration around the interface information

If one pays attention to different types of interaction in situation of collective work, it may reveal that depending on certain conditions, designers may opt naturally for *coordination* or *cooperation* mode of collaboration.

- *Coordination mode* represents an adjustment by iterative exchange on the interface information between the *provider* (activity 1) and the *user* (activity 2) (figure 3). However the involved designers are not collectively committed to produce or verify the interface information. Each one (provider or user) is responsible of his own activity. The provider is the one who triggers the coordination mechanism. Interface information involve constraints in both sides (provider and user) that are not confronted. In that case the activities decomposition, their sequencing, the interface information, the designer's team and the objectives could be *identified*. For instance, one considers the coordination between the hydraulic engineer and the civil engineering designer (figure3). The first one has the objective of estimating the *rate of flow* (represented in hydraulic shape document) whereas civil engineering designer has the objective of estimating the *head* (represented in the adaptation of installation drawing) that hydraulic engineer transmitted to him. Both the *rate of flow* and the *head* are iteratively adjusted.

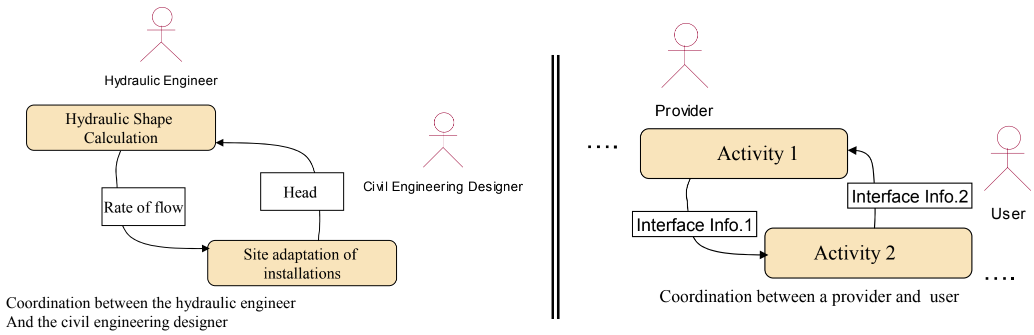


Figure 3 Coordinative activities.

Moreover, the sequence of these activities is identified and interface information play the role of *resources* that are produced or transmitted from one activity and are used by another one.

The coordinative activities could be *predictable.* The involved design team, the sequence of work (activities decomposition and scheduling) and the interface information are known beforehand (could be at the beginning of the project). It corresponds to the fulfilment of a pre-identified objective of management such as activities planning; resources evaluation…etc. That is the case for the predictable coordination between the hydraulic engineer and the civil engineering designer (figure3).

- *Cooperation mode* [18] refers to activities that are executed by a group of actors who are collectively committed to produce hypothesis, argumentation and solution of a design problem (figure4). As the coordination case, it is also a question of negotiation on interface information. However, the estimation of the interface information has to fulfil common objectives that are built conjointly by the actors and that are not necessarily known beforehand. Each of these contributors could have their own objectives which are known by the other actors. It is also a question of contributor's constraints confrontation. Sometimes these are contradictories. For instance, one has to consider the "power plant dimensions" cooperative activity between civil engineering and mechanical engineering designers (figure4). One of the common objectives consists of identifying the width value of the power plant. The *minimum width* is required by the civil engineering designer so as to fulfil power plant structure constraints, concrete volume limits, etc. whereas the *maximum width* is required by the mechanical engineering designer so as to fulfil installed power, machines volumes constraints, overall external dimensions of machine, etc. Moreover, the contributors share knowledge and design roles (*bigger is the power plant width smaller is the installation run fast and rare are the maintenance problems*) that facilitate mutual understanding. The *interface information* are shared as a common representation. No partial order for their using is identified. The cooperative activities may also be predictable (design review) or not predictable needed for a specific purpose.

In the next section, we introduce a framework that allows the management of both the coordination and the cooperation mode of collaboration where the first one represents a project organisation level and the second one is more a facilitation of co-production level.

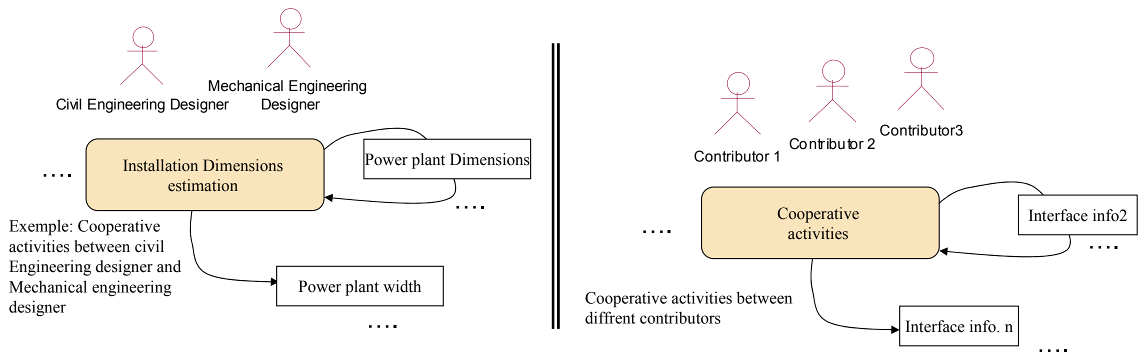


Figure 4 Cooperative activities.

5. The Proposed Conceptual Framework

5.1 Overview

In the section (§4.1) above, we have highlighted that during the design phase the interface information may evolve from *draft to deliverable* states. However their diffusion commits their provider to the other design actors. In fact if interface information is diffused in a certain state that does not fit the requirements of their users, this may give rise to design iterations problem and the actors involved have to do reworks until reaching the required result. We argue that the management systems of information in collaborative design activities require the establishment of a framework basing on *four levels of information diffusion* that we refer as *working spaces*.

First one is called *public working space*. It organizes the sharing of *public information* that means *deliverables* of the design activities and some others intermediary objects identified in the design process. These objects are essentially closed ones. They are published in that working space when they are validated, which means when they reach the deliverable state. The actual PDM systems offer much functionality to manage the sharing of this level of validated information. The evolution of this information could be based on specific lifecycle or Engineering Change management processes.

On the opposite, there is the *private working space*. In that working space the designer arrange his *drafts* and personals data. These objects do not have any existence in the formal framework of the project. They are not shared and they don't have to.

A third level is the working space that corresponds to the *cooperation* (§4.2) around *exhibit information* (§4.1). They are the draft of the solution considered as a sharable within the personal network. This working space is called *proximity working space* because it includes actors of the personal network of the producer. The working space is open by an actor who wants to confront his ideas with partner's point of view in order either to construct argumentation or to validate ideas. Some actors of this ad-hoc collaboration could be inside the project design team some could be guests and may be outside the design project team. The proximity working space is open at any time an actor needs to expose a draft as an *exhibit* to a group of "friendly" actors. These working spaces correspond to *not predictable* activities in the sense that they are not known beforehand and they emerge from the design problems treated by the actors. The actor closes the working space when the interface information could change from *exhibit* state to at least *enabled* state.

Enabled interface information are encountered in the last working space called *project working space*. This intermediary level is the level of sharing interface information in the constituted design team. This corresponds to the *coordination* (§4.2) of the *predictable* design activities among designers. In other words that is a working space where downstream and upstream activities organisation is done *beforehand* so as the interface information (from upstream activity) fulfil their user's requirements (in downstream activity) (§4.1). This planning is possible because of the design team knowledge.

As said above (section §4.1, paragraph §5), the evolution of the interface information from draft to enabled trace state is not linear. Thus at any time of the design, one can goes from proximity (exhibit) to either private (draft) or project (enabled) working space or from project to either private or exhibit working space and vice versa.

In the section (§4.1) we considered that user's requirements could be either the conditions about the product (the high of the dam should be less then 100 meters) or about maturity condition (the high of 40% of precision, 50% of stability…).We consider that the first ones are within the competence of the designers and it could be ad-hoc to instrument them. Moreover, for the reasons mentioned above (section §5, paragraph 1), we propose to pay attention to the interface maturity requirements and to offer instrument to perform it. Thus when the interface information (the intermediary object globally, the "part" of it or even an elementary characteristic) move from a working space to another, the actors can characterize (cf. § 2.2) them. In another words, the actor publishing the interface information in the shared working space specifies the maturity criteria (certainty, stability, precision, completeness) and the expected date of its disposal. In the proximity working spaces, we use the term of exhibit maturity to qualify the maturity level of interface information. For the project working spaces, target maturity levels called enabled maturity could have been expressed in an agreement between provider and the different users of the information. Hence the focus is put on the proximity and the project working spaces where *non mature* interface information could be shared.

The table (2) summarizes the key features that allow one to identify whether the encountered design situation corresponds to the proximity working space or to the project working space.

Table 2. Proximity Vs Project Working Spaces

Key Features	Proximity Working Space	Project Working Space
Predictable (known beforehand)	**No** *(e.g. civil. Eng. designer and the geological expert for verifying and validating the geol. Data)*	**Yes** *(e.g. hydraulic engineer and civil.eng.designer for hydraulic shape calculation)*
The identification of the sharing of work[10]	**Not identified** *(e.g.hydraulic engineer and civil eng.designer for longitudinal bed profile cooperation)*	**Pre-planed sharing** *(e.g.hydraulic engineer and civil.eng.designer for hydraulic shape calculation)* Not identified *(e.g. Project reviews)*

[10] The sharing of work means: the decomposition of work into activities, the affectation of the designer's team, the sequencing of the activities, the identification of the interface information and the identification of the objectives.

The aim of the co-operation	**Argumentation validation** *(e.g. to call on expert validation)* **Construction of the argumentation** (*e.g. civil.eng.designer and mecha.eng.designer for dimensions estimation*)	**Management Objectives** (planning, evaluation…) *(e.g.hydraulic engineer and civil.eng.designer)* *(e.g. project reviews)*
Common objective(s)	**Yes** (*e.g. civil.eng.designer and mecha.eng.designer for dimensions estimation)*	**No** *(e.g.hydraulic engineer and civil.eng.designer for hydraulic shape calculation)* **Yes** *(e.g. project reviews)*
Interface information sharing	**Sharing common Representation** *(argumentation construction)* **Resource communication** *(argumentation validation)*	**Resource communication**
Knowledge sharing	**Yes**	**Yes/No**
Variability of designers team	**Variable Design team** ***(personal network and trust relationship)*** *(eg. Civil eng. designer and geologist expert team)*	**Fixed design team** *(the project design team)*
Quantifiability of objectives maturity of interface information	**Not quantifiable maturity objectives**	**Quantifiable maturity objectives** *(enabled maturity)*
The required state of the interface information to be published in the working space	**Exhibit** *(e.g .the geological profile submitted by civil eng.designer to geologist for validity verifying)*	**Enabled-trace** *(e.g. the hydraulic shape document transmitted to civil.eng.designer)*

The section (§5.2) below introduces some functional requirements of the future interface information management system in the context of collaborative (cooperation and coordination) design processes. For each working space, are associated a type of activity (predictable or non-predictable), the actors involved, the objects or interface information exchanged and their relating maturities (enabled and exhibit maturities).

5.2 Project working space management

We are interested in predictable coordinative activities that could be defined at the creation of the project. The predictable cooperative activities such as project reviews do not take part in this work because they are not considered as relevant situations for maturity management question. To identify these activities, actor's practices analysis are required during design process using for instance «*structured expert interview process*» (see [20]). The support of such activities can partly be realized by traditional workflow systems [21] (most PDM tools integrate workflow system). These systems require the definition of activities and their resources (interface information and actors involved in these activities) beforehand.

From our field study (HECEDO), we have revealed it would be preferable to consider only recurrent particularly critical[11] activities. As an illustration, we consider the predictable collaborative activity between hydraulic engineer and civil engineering designer. It is known

[11] The activity which increases process lead time.

(from previous experiences) that hydraulic engineer produces hydraulic shape containing, in particular, the interface information 'rate of flow'. This latter will be diffused to the civil engineering designer in order to perform the installation implantation activity in other words to estimate the "head". However as the civil engineering designer can not wait for completely mature rate of flow value to perform his activity. An agreement has to be established *beforehand* between the hydraulic engineer and the civil engineering designer to fix a *minimal maturity level* required. It is, as we called it above, an *enabled maturity level*. The measure of this maturity is introduced in order to express the fact that the enabled state of interface information depends on both its provider and its user judgments. Therefore interface information can be enabled for a couple of producer/user and not for others. The providers and the users could also discuss the expected date of publication of the interface information. Thus predictable activity scheduling could be performed and updated as the process goes along according to enabled maturities levels of interface information and their expected date of publication.

The figure (5) shows that the project working space is characterised by:

- Designers from project team transmitters and receivers of interface information,
- Interface information to be exchanged.
- Enabled maturity levels and expected publication date relating to interface information defined beforehand in an agreement between the transmitter and the receiver.

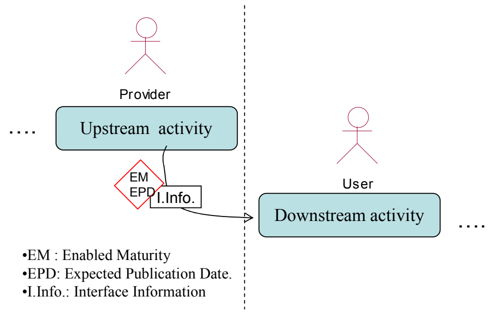


Figure 5 Project working space and predictable activities coordination.

5.3 Proximity working space management: Cooperation functional requirements

Identifying a predictable collaborative activity allows a useful framework for design actor's coordination. Setting up maturity level mechanisms makes the reliability of exchanged information explicit during predictable collaborative activities. However, this phase decomposition into predictable activities comes up against opportunistic character of design collaborative activities.

In order to reach enabled maturity levels, the actors create and execute non-predictable collaborative activities where exhibit information can be discussed. These activities can not be identified beforehand; however they are essential for informal information validation purpose. For instance, one can consider power plant technical draw making as a predictable activity done by designer. To perform this predictable activity the designer (the host) can open proximity working space that mean carrying out non-predictable activities with others specialists (guests) belonging to project team or not. Therefore one has to establish mechanisms that allow a designer to create non-predictable cooperative activities in order to fulfill particular emerging design requirements. Interface information is created by the host at the same time as the creation of the proximity working space. It may be evolved among the proximity working space by the contributors (either the host or the guests). Interface information is *characterized* by its publisher before being placed in that working space. The corresponding estimated maturity is called *exhibit maturity*. When interface information reach an enabled maturity it will be published in the project working space and the corresponding proximity working space could be closed by the host. Allowing characterization of interface information in proximity working spaces may facilitate cooperation among design teams by making exchanged information and their reliability explicit.

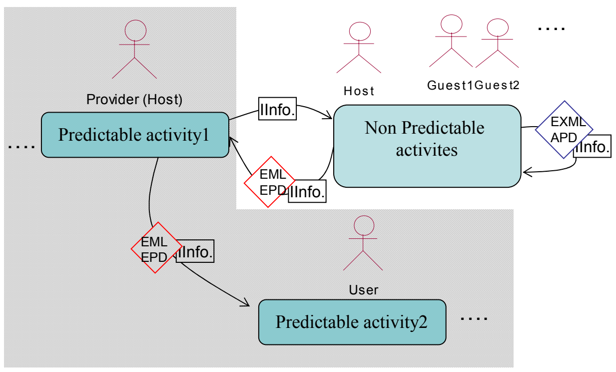
The figure (6) shows that the proximity working space is characterised by:

- Designers from project team or not contributing to non predictable activities. They cooperate around interface information.

- The host designer who creates and closes the proximity working space is distinguished from the guest designers invited by him.

- Interface information identified at the same time as proximity working space is created (by host) or activated (by the host or any one among guests).

- Exhibit maturity level associated to interface information published in proximity working space.



•EM : Enabled Maturity
•EPD: Expected Publication Date.
•IInfo: Interface Information
•EXM: Exhibit Maturity
•APD: Approximate Publication Date

Figure 6 Proximity working space and non predictable activities cooperation.

6. Conclusion

In that paper based on our observation in design office and concepts of social studies of design activities, we propose a conceptual framework to support *non mature information* during the strong collaborative activities. This is keeping with information sharing approach in stead of their diffusion. Thus we propose four frames of work referred by *working spaces.* Basing on the sharable working spaces (proximity and project), on the interface information (supported by intermediary objects) and the maturity concepts, we propose the possibility to handle both the project management and the day to day collaborative activities facilitation. In fact, we propose to offer the possibility to members of project team to express and agree on their expectance (interface information and their relating enabled maturities) beforehand at different milestones. In addition to that, we suggest a dynamic activation of proximity working spaces or even a private working space when problems occur on enabled information or to validate exhibit information. One can then publish it in project working space when its enabled maturity is reached. From technology point of view, this corresponds to a system integrating both workflow (for project management purpose) and groupware systems (for collaboration facilitation purpose) communication capabilities. It needs also to enrich the life cycle management of information by allowing the expression of the maturity levels.

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