Articulation of verbalizations and useful information in BIM coordination meetings

Anabelle Rahhal, Samia Ben Rajeb, Pierre Leclercq

In Le travail humain 2025/4 N° 88 , pages 335 to 361
Publisher Presses Universitaires de France

ISSN 0041-1868
ISBN 9782130877592
DOI 10.3917/th.884.0335
Uploaded: 01/19/2026

EMPIRICAL STUDIES
RECHERCHES EMPIRIQUES

ARTICULATION OF VERBALIZATIONS AND USEFUL INFORMATION IN BIM COORDINATION MEETINGS

ARTICULATION DES VERBALISATIONS ET DES INFORMATIONS UTILES EN RÉUNION DE COORDINATION BIM

BY/PAR ANABELLE RAHHAL [1], SAMIA BEN RAJEB [2] ET PIERRE LECLERCQ[1]

SUMMARY

Building Information Modeling and Management (BIM) coordination meetings play a critical role in facilitating collaboration among diverse stakeholders involved in construction projects. These meetings assemble professionals from multiple disciplines, including architects, engineers, project owners, and contractors, with the objective of addressing project issues, sharing information, and aligning efforts. Given the inherent complexity of construction workflows and the increasing reliance on digital models, effective communication and coordination in these meetings are essential to ensure project success. This paper presents an empirical investigation of verbal interactions occurring during BIM coordination meetings conducted within a controlled experimental framework. A three-phase data collection protocol was employed to capture and analyze stakeholder exchanges. Central to this methodology is a specifically designed observation grid, consisting of four analytical levels and thirteen verbalization categories tailored to the BIM coordination context.

The principal aim of the study is to characterize the types of communicative exchanges among participants and to identify key informational elements that contribute to decision-making processes, particularly when the digital model serves as the primary mode of information presentation. Results indicate that the majority of exchanges consist of proposals and arguments, while verification and divergence phases are limited. Instances of counter-argumentation are also infrequent. A notable finding highlights the pivotal role of the BIM coordinator as a facilitator who steers discussions toward convergence and collective decision-making. The coordinator's technical proficiency in BIM software, comprehensive knowledge of the project, and capacity to structure dialogue are instrumental in resolving conflicts and ensuring meeting efficiency. Furthermore, the project

1. Université de Liège – a.rahhal@uliege.be (auteur correspondant) ; pierre.leclercq@uliege.be
2. Université Libre de Bruxelles – samia.ben.rajeb@ulb.be

Le Travail humain, tome 88, nº 1/2025, 335-361

manager (MOE) assumes a critical function at decisive moments, guiding and validating decisions based on a deep understanding of the project's technical specifications.

Useful information emerges gradually over successive verbalizations, often requiring iterative contributions before reaching resolution. Such information primarily concerns digital modeling and the collaborative organization of work, impacting both short-term meeting outcomes and the long-term coordination process. Although the experimental design involving student participants restricts the generalizability of the findings, the study offers valuable insights into the fine-grained mechanisms of solution co-construction during BIM coordination meetings. The paper concludes with recommendations to enhance coordination practices and improve BIM coordinator training, emphasizing mastery of tools, constructive communication, and systematic follow-up of decisions.

Keywords: *coordination, BIM, information, utility, interaction, decision-making.*

RÉSUMÉ

Dans cet article, une méthodologie de récolte de données en trois temps est mise en place afin d'analyser et de visualiser les échanges verbaux en réunion de coordination de projets de construction menés BIM (Modélisation de l'Information du Bâtiment). Nous mettons en place une grille d'observation des réunions de coordination BIM qui se déroulent dans un cadre expérimental contrôlé. Cette grille comprend finalement quatre niveaux et treize définitions de verbalisations adaptées à ce cadre. Le but de cette étude est de comprendre les types d'échanges entre acteurs et de tracer les informations utiles qui conduisent à la prise de décision, quand la maquette numérique est le mode de présentation principal de l'information. Les résultats soulignent l'importance du rôle du coordinateur BIM dans la conduite des discussions, la recherche de convergences et la prise de décision collective. Les informations utiles émergent progressivement au fil des verbalisations, en lien avec la modélisation numérique ou l'organisation du travail collaboratif. Le rôle du maître d'œuvre (MOE) s'avère également crucial à certaines étapes pour orienter ou valider les décisions. L'étude met en lumière les mécanismes fins de co-construction de solutions en réunions de coordination. Des pistes sont proposées pour renforcer les pratiques de coordination et enrichir les formations BIM, avec une perspective d'extension à des contextes professionnels réels.

Mots-clés : *coordination, BIM, information, utilité, interaction, prise de décision.*

I. INTRODUCTION

I.1 Context

In an interactive communication context, information is defined as any indication, documentation or detail transmitted with a specific

purpose, such as problem-solving (Martin, 2001). It becomes a tool for communication and teamwork, contributing to collective performance, especially during meetings (Darses, 1997; Gronier, 2000). In BIM coordination meetings, participants exchange information directly and decide on actions to address or resolve conflicts.

The term "BIM" refers to a geometric model enriched with building-specific data (Shepherd, 2019) and detailed information about the project components. The BIM approach relies on the active collaboration of all project stakeholders to facilitate cooperation between diverse actors (Poirier *et al.*, 2018). This approach is not limited to geometric modelling but also integrates an information-sharing process, forming a collaborative database. BIM therefore enables the creation and use of construction data in every phase of the project: design, construction, and operation. In the scope of our research, BIM is approached from two perspectives: on the one hand, as an information management process for project management (Chaudet, 2019), and on the other hand, as a teamwork management tool allowing various stakeholders to collaborate using an enriched model (Levan, 2018).

Faced with growing challenges in the construction sector, such as the proliferation of digital technologies and increased project complexity, it is crucial to analyse information exchange processes in order to improve and optimize existing work methods and practices. This article presents a research methodology focused on observing and visualizing information exchanges within BIM coordination meetings, which are key moments of communication and interaction among stakeholders (Mehrbod *et al.*, 2019).

I.2 The meaning of exchanged information in BIM meetings

The model is used by BIM coordinators in particular when presenting and explaining conflicts and issues identified between the so-called disciplinary models, to explain the progress of model coordination (Forgues *et al.*, 2018). The BIM model constitutes one of the main modes of presentation for exchanges in which viewpoints are discussed and decisions are made collectively. Indeed, decision-making exchanges between actors include finding common solutions to a problem, and accepting or rejecting proposals. In our experimental framework, we aim to ascertain at what point the BIM digital model takes on the role of a collective intermediate object, and what types of exchanges between actors lead to decision-making in BIM coordination meetings?

This research question addresses the key decision-making concepts in collaborative work, whether one or several concepts. Our study analyses several coordination meetings in which actors discuss the digital model for various agenda topics.

The goal is to identify the types of exchanges that lead to decision-making in BIM coordination meetings. Indeed, information is meaningful as a decision-support tool, allowing actors to choose, decide and act. Its

value is thus linked to how it is used to make decisions. Information is also a collective work tool; during a coordination meeting among project stakeholders, the information shared by each person, and specifically by the coordinator, will help improve the team's overall performance by adjusting each member's actions.

I.3 Controlled experimental framework

Within the framework of four editions of a BIM experiment (SDC BIM), each lasting four months (Rahhal *et al.*, 2020), 75 first-year master's students in Civil Architectural Engineering at the Faculty of Applied Sciences in the University of Liège, worked in groups to develop eight BIM projects. The experimental protocol of this research was designed to simulate professional practices and approximate real conditions. It integrates emerging methods and tools that promote collaboration in an unprecedented technological context.

The organization of collaborative work is entrusted to the participants, who distribute the various tasks themselves. Specific roles are assigned, such as BIM coordinators and BIM modellers, each specialized in a domain such as architecture, structure or specialized technical disciplines. The BIM projects selected originate from previous design work undertaken in an architectural workshop at the University of Liège by first-year master's students in architectural engineering. This workshop is distinguished by its approach, combining spatial composition and project management within the framework of a public competition to design a contemporary facility.

The technical detail for these projects was provided by the students from ULiège and they were partially pre-sized by students from the École des Mines d'Alès, thus offering an advanced level of project design between the detailed preliminary design (APD) and the execution phase (EXE). The choice of projects at such an advanced stage aims to highlight BIM's contribution in this phase, where digital models can be exploited in multiple ways. The design documents, plans, and sections, as well as the technical pre-sizing reports (structure, chauffage, ventilation, etc.) are provided to the different actors in the experiment to support their work.

I.4 Bim coordination meetings: an observed situation

In this context, we chose to observe BIM coordination meetings to analyse actual exchanges between project actors. The meetings are held weekly for an average of 60 minutes, and are led by one or more BIM coordinators. They benefit from logistical tools, notably a digital wall board to visualize and annotate the project. In total, 22 BIM coordination meetings were analysed over four years: eight in 2019, eight in 2020, four in 2021, and two in 2022. In this article, the observation results focus on data from 2020.

The agenda is set in advance by the coordinator and his/her team according to project progress. Topics discussed include the identification of geometric conflicts between models from different disciplines and the resolution of technical and organizational problems encountered during the project. These meetings mainly take place in person but can also be held remotely if necessary. Each participant has physical supports such as laptops, graphic tablets equipped with digital styluses, and a shared interactive board for the whole group.

II. THREE-STEP OBSERVATION METHODOLOGY

II.1 Information characterization in bim coordination meetings

In the context of our study, we designed an observation grid to collect the necessary data in sufficient quantities to analyse exchanges during BIM coordination meetings. This analysis required a precise description of the specific information exchanged in a communication context primarily based on the use of BIM models. In the field of information and communication sciences, several characteristics are associated with exchanged information. Thus, the first initial observation grid is based on these six main criteria:

(1) Time, measured between two new points discussed, which tells us the time spent on one idea at a time;
(2) Novelty of the point discussed, with each new point brought up by the coordinator defined as a new element in the conversation;
(3) Subject of the information exchanged;
(4) Presentation mode of the information exchanged, that is the set of artefacts used to explain the information exchanged;
(5) Information medium, that is both the software and the physical support used;
(6) Stakeholders in the exchange that were impacted by this point in the conversation.

This grid was used for the transcription and analysis of the first eight meetings of SDC BIM 1 in 2019. The criteria were refined and supplemented with scientific literature on the subject, resulting in the creation of several observation subcategories for each criterion, as shown in Figure 1. These subcategories are specific to the information exchanges observed in BIM coordination meetings and were already included in a publication relating to this doctoral work (Rahhal *et al.*, 2023) [3].

3. Rahhal, A., Ben Rajeb, S., & Leclercq, P. (2023, May). Suivre un flow d'informations : Entre l'observation et la visualisation des échanges lors des réunions de coordination BIM. In *ModACT 2023-Modélisation de l'Activité*.

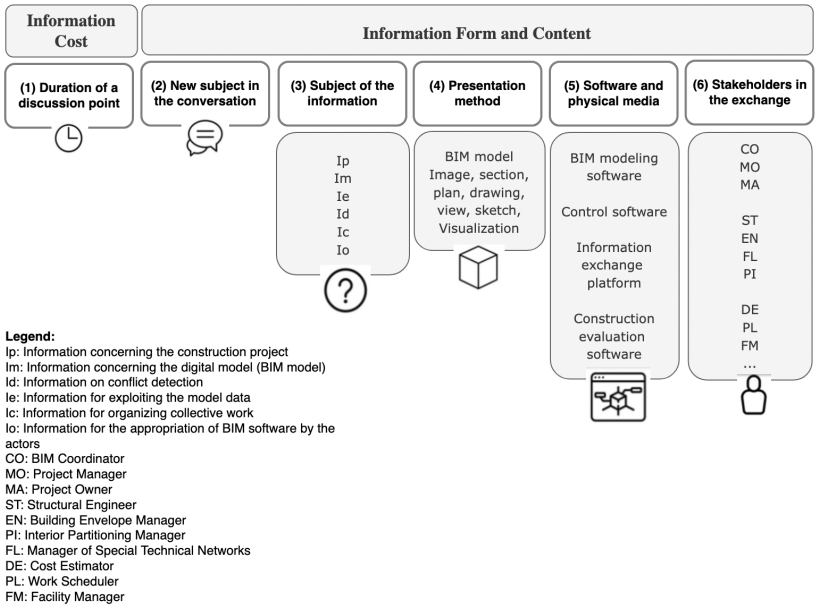

Figure 1. Diagram providing a synthesis of all criteria subcategories for characterizing information exchanges in BIM coordination meetings, in SDC BIM 1.
Figure 1. Schéma illustrant en synthèse toutes les sous-catégories de critères pour la caractérisation des échanges en réunion de coordination BIM, dans SDC BIM 1.

II.2 Second round of observations

II.2.A Extension of observed criteria

Our second observation grid expands upon the first one to evaluate two additional characteristics related to the information exchanged, as shown in Figure 2:

1. Meaning: defined as the role of the information exchanged within a specific context, for example, as a decision-support tool, a communication tool or a tool for collective work (Boton *et al.*, 2021).
2. Quality: primarily the usefulness of the information exchanged, demonstrating its use value by meeting a collective need or responding to a project stakeholder's requirements (Harrathi & Calabretto, 2006).

The second phase of coding in our grid was carried out as part of the 2020 SDC BIM 2 experiment, focusing on the negotiation processes and the conflicts arising from differing participants' viewpoints during meetings. Moreover, it allows for a hierarchy of verbal exchanges by highlighting the solutions adopted as well as alternative solutions and the debates they did or did not provoke. These deliberation passages take the form of collective argumentation episodes (Darses *et al.*, 2001; Martin,

2001), generally occurring during work meetings in person, but also remotely.

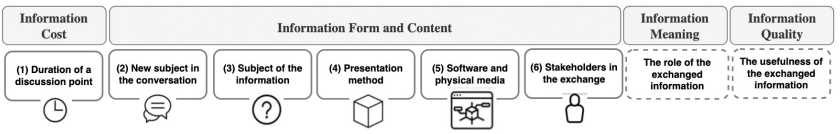

Figure 2. Diagram illustrating the criteria observed in our second stage of observation in SDC BIM 2.

Figure 2. Schéma illustrant les critères observés de notre deuxième étape d'observation dans SDC BIM 2.

II.2.B Definition of levels and categories of verbalizations

The "argumentative level" has evolved between its creation and subsequent use (Détienne *et al.*, 2005; Martin *et al.*, 2001). Here, we present the adapted and synthesized version from Gronier (2000, 2010), which reprises the classification proposed by Martin (2001), Martin *et al.* (2001) and Détienne *et al.* (2005). This coding grid breaks down verbal statements exchanged during project meetings into four levels (Gronier, 2010, p. 156), to which we add a fifth, level zero, to account for the well-structured and organized aspect of a BIM coordination meeting, with agenda points that are clearly defined in advance. Thus, the five levels of verbalization are as follows:

- Level zero in the second grid concerns the agenda points of the meeting; it corresponds to point (2) in the first SDC BIM 1 grid, representing new point introduced by the coordinator and defined as a new element in the conversation.
- Level one concerns the general elements on which debates between meeting participants are based; in our grid, Level 1 covers proposals, requests or descriptions of a problem encountered relating to a point on the agenda (Level 0). Level 1 also includes points that do not require the group to adopt a position (regulation).
- Level two is characterized by illocutionary elements that directly support the general elements. In other words, it concerns the different reactions of actors to the topic raised by the coordinators.
- Level three, consisting of divergences and convergences, articulates Level 1 with Level 2, as described previously; Level 3 is the result of interactions.
- Level four aims to conclude the exchange and interlocutory procedures, beginning with the proposal of the agenda point; Level 4 in our grid is the conclusion of a debate on the subject brought up by the coordinator, with or without decision-making.

When comparing the different categories of verbalizations proposed by the COMET researchers (Darses *et al.*, 2001), as well as Beers (as

presented by Defays) (2015), Martin (2001) and Jaccard (2020), the definitions are sometimes similar or distinct under different names. To select the most appropriate ones for our study of BIM coordination meetings, we compared concepts and retained 13 categories that were relevant for analysing exchanges and decision-making during BIM coordination meetings. We sometimes changed the names or adapted the definitions. These categories are accompanied by four additional categories aimed primarily at specifying the verbalization category specific to the BIM coordinator at the start of the agenda point, providing clarifications or taking into account injunctions that regulate the discussion.

The 13 definitions of categories adopted or modified, on which our study is based, are as follows:

– Proposal: Expression of an idea in dialogue (a solution, goal, inferred datum, way of doing something, etc.);
– Verification: Direct or indirect request to clarify the intended meaning of a verbalization;
– Argument: Reason given to support a proposal;
– Counter-argument: Reason given to reject a proposal;
– Reiteration: Repetition of an element to reinforce an idea;
– Repetition: Request for the repetition of a verbalization;
– Reintroduction: Reintroduction of an element already mentioned and addressed during the meeting;
– Divergence: Misunderstanding, doubt or rejection of a solution;
– Acceptance: Agreement with the proposal made by the coordinator;
– Rejection: Misunderstanding, doubt or rejection of the coordinator's proposal
– Convergence: Acceptance of a solution;
– Positive stabilization (+): After one or more convergences; actors agree on a solution;
– Negative stabilization (–): After one or more divergences; actors do not reach an agreement and there is no change in the status quo.

The five additional categories added for our study, adapted to the context of a BIM coordination meeting, are:

– Request: Oral formulation of a question or a request addressed to one or more employees to obtain information;
– Implicit positive stabilization: Actors reach an agreement expressed implicitly;
– Addition: Addition of information to complement the discussion on the subject without adopting a position (inspired by Martin's functional grid levels and the nuanced evaluation of COMET);
– Description of a problem: Oral presentation and formulation of a problem encountered by the BIM coordinator, aimed at one or more persons;
– Regulation: Addition of information to complement the discussion that does not require decision-making, or as a control element in the problem-solving task or conversation organization;

Below, in Table 1, we present our four levels of classification with the different categories associated with verbal exchanges (adapted from Gronier, 2010).

Table 1. Summary of coding levels for the analysis of debates between viewpoints (adapted from Gronier, 2010, p.158).
Tableau 1. Résumé des niveaux de codage pour l'analyse de la confrontation de points de vue (adapté de Gronier 2010, p158).

Level 1	Level 2	Level 3	Level 4
– **Proposal:** Expression of an idea in the dialogue (a solution, goal, inferred datum, method, etc.) – **Request:** Direct verbal request as a question addressed to one or more employees to obtain information – **Problem** Description: Presentation of a problem encountered by one or more members of the group – **Regulation:** Expression of information during the discussion that does not require decision-making, or serves as a control element in the problem-solving task or the organization of the conversation	– **Verification:** Direct or indirect request for clarification of the intended meaning of a statement – **Argument:** Reason given for supporting or justifying a proposal – **Counter-argument:** Reason given for rejecting a proposal – **Reiteration / Problem Description:** Repetition of an element to reinforce an idea – **Repetition:** Request for the repetition of a statement – **Addition:** Addition of information to complete the discussion, related to the subject – **Reintroduction:** Reintroduction of an element already mentioned and addressed earlier in the meeting	– **Divergence:** Misunderstanding or doubt about a solution – **Convergence:** Acceptance of a solution or proposal – **Rejection:** Non-acceptance of a proposal – **Acceptance:** Positive evaluation of a proposal	– **Positive Stabilization:** After one or more convergences or acceptances, the actors reach an agreement – **Negative Stabilization:** After one or more divergences and rejections, the actors do not reach an agreement and the status quo remains – **Implicit Positive Stabilization:** The actors reach an agreement expressed implicitly

In this second round of grid encoding, we created a section entitled "Levels and Categories of Verbalization":

– For Level 0, a single category: "Point", referring to each new agenda item.
– For Level 1, four categories: "Proposal", "Request", "Problem Description", and "Regulation".
– For Level 2, two categories: "Reaction" and "No Reaction", which overlap with "Who?" – that is the participants involved in the exchange, already included in the first observation grid.
– For Level 3, we included the categories: "at least one convergence", "at least one divergence", "an acceptance" or "a rejection".
– Level 4 is inferred based on our decision tree (illustrated in Figure 3) and is not manually encoded in the grid.

Decision-making occurs when the participants reach either implicit or explicit positive stabilization. In order to maintain consistency and objectivity in the verbalization coding process, we established a decision-making grid, illustrated in Figure 3 (inspired by Defays, 2015) to resolve certain ambiguities during coding.

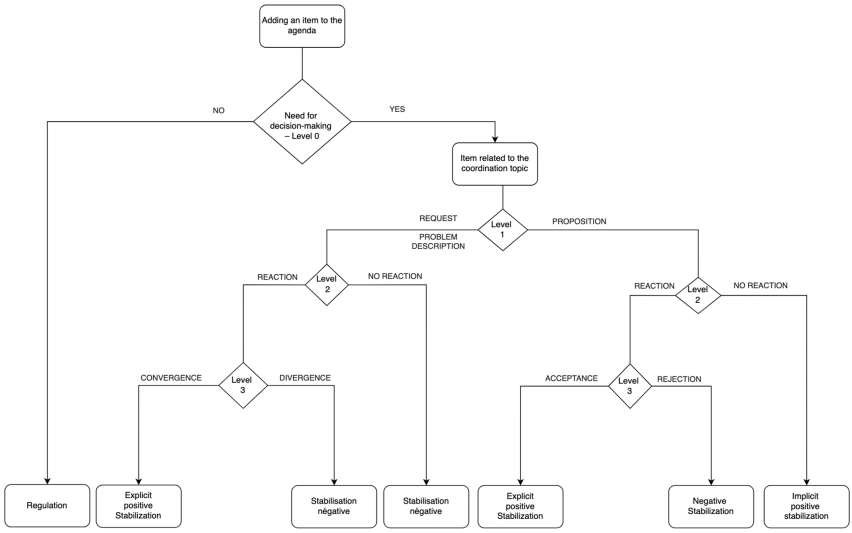

Figure 3. Decision tree for verbalization coding in SDC BIM 2 meetings.
Figure 3. Arbre décisionnel pour l'encodage des verbalisations des réunions de SDC BIM 2.

The second round of coding enabled us to identify argumentative episodes that led to either an explicit or implicit positive stabilization. For our analysis, we consider collective argumentative episodes to be those that:

– were initiated by the BIM coordinator;
– belonged to the "request", "problem description" or "proposal" category in Level 1, requiring the group, or one or more members, to make a decision;
– involved at least two categories of information objects, whether organizational, technical or technological;

And those that:

– elicited at least two reactions from distinct group members;
– resulted in at least one convergence;
– led to a positive stabilization, where – after one or more convergences or acceptances – the actors reached an agreement.

II.3 Third round of observations and the utility of information

Following the first two rounds of observations, we identified several areas for improvement, as well as adaptations that were necessary for the continuation of our analysis:

– The definition of speaking turn does not allow coding project participants' ideas in sufficient detail. For our transcription method, a smaller unit of observation is required in order to identify only one idea per coding line, as illustrated in Figure 4.
– We will use time-related data as analytical material to better understand the verbalization sequence.

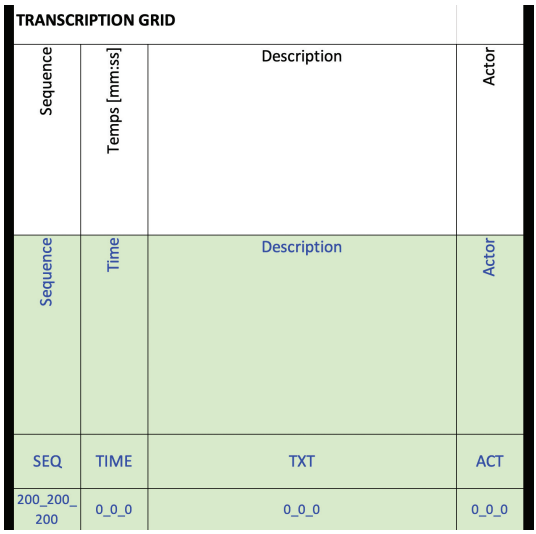

Figure 4. The first coding area of the grid allows, for each sequence of our episode, the duration, description and the actor involved to be specified.
Figure 4. La première zone de codage de la grille, permettant pour chaque séquence de notre épisode, de préciser son temps, sa description et l'acteur concerné.

The third and final round of coding focuses on the selected argumentative episodes to be studied with a finer granularity, which allows us to provide more detail for the categories observed for Levels 2 and 3, as shown in Figure 5, as well as the purpose of the information and the modes of presentation, as shown in Figure 6.

Each line of verbalization has a unique coding and a reference number. However, there are three special cases of coding:

– new points do not have references;
– a stabilization always occurs before a topic change;
– if the coordinator makes a proposal (Level 1) without feedback or reaction from the group (Level 2), then the positive stabilization is

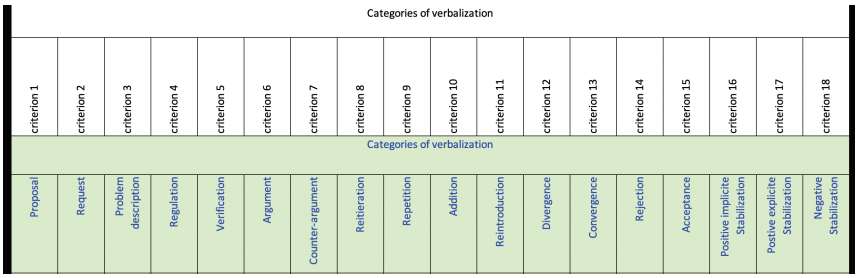

Figure 5. Excerpt from the second coding area of the grid, including all the verbalization categories.

Figure 5. Extrait de la deuxième zone de codage de la grille, comprenant l'ensemble des catégories de verbalisation.

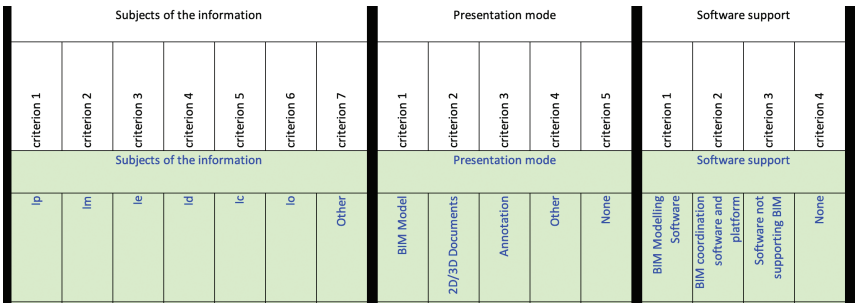

Figure 6. Excerpts from three sections of the transcription grid, including the different types of information objects, modes of representation and points of focus.

Figure 6. Extraits de trois zones de la grille de retranscription comprenant les différents objets de l'information, les modes de représentation et les points d'attention.

considered implicit. This is the only case of implicit positive stabilization.

II.3.A Detection of the usefulness of exchanged information

In our final coding grid, we focus on detecting "useful" information, as shown in Figure 8. In common understanding, usefulness is the quality or characteristic of something that satisfies a need, is advantageous or profitable, or even timely. This definition includes subjective and temporal dimensions highlighted in relevance studies but also reveals the vagueness and ambiguity of the concept. Like relevance, usefulness is an ordinal measure that allows elements to be compared to each other, rather than a cardinal measure with an absolute value.

In information science, the concept of "usefulness" refers to the practical value or importance of information in a specific context. It involves evaluating how well information meets a user's needs, assists decision-making or contributes to achieving a particular goal. For information to be declared "more or less" useful, three criteria must be met:

– It responds to a need expressed as a request or problem description (Tricot *et al.*, 2003)
– It leads to at least one convergence and thus to a decision
– It presents a potential usage value (a subsequent task planned to achieve a goal) (Mayère, 1997)

The usefulness of information depends less on the project participants' knowledge than on the intended use of the received or retrieved information. The true value of information lies in its usage value, which manifests itself through constantly renewed interpretations (Mayère, 1997). In this context, the ability to understand, read, analyse and synthesize information and documents, and relate informational elements to one's own knowledge is crucial. Although the concept of usefulness is related to relevance, it places less emphasis on the complex intellectual process necessary to master information processing.

II.3.B Data visualization

Before discussing results, the data visualization platform used to visualize and represent argumentative episodes will be described. To represent our argumentative episodes, we work with the "CommunTools" tool, which presents selected episodes chronologically, according to verbalization categories that lead to decision-making and analysis. This tool, dedicated to collective activity analysis, is capable of:

– structuring pre-coded data in Microsoft Excel to calculate relationships between different variables and according to actors;
– offering suitable visual formalisms that facilitate reading results.

We chose to use CommunTools in our work because, on the one hand, it meets our needs by allowing us to study the temporal articulation of the "verbalizations" and "information objects" variables, and on the other hand, our data are compatible with this analysis tool. We illustrated the temporal articulation of each verbalization category for all actors and for the different information objects. The timeline form also enables us to observe the sequence of verbalizations of each actor and highlight key decision-making moments where the information proves useful, which implies a reading of the exchange process via argumentative levels.

In our data visualization diagrams, the vertical axis shows the different actors according to their roles (CO, FL, PI, MOE, ST), as well as categories of "spots" (usefulness, positive stabilization or agenda point), and the horizontal axis shows the time and order of interventions in seconds. A specific colour represents each type of actor intervention, with verbalization categories such as "Proposal" (dark blue), "Argument" (orange) and "Verification" (light yellow). Categories concerning the information object are also represented in different colours, for example "Ip" (dark blue), "Im" (normal blue), "Ie" (sky blue) and "Id" (dark green). The colours help track the types of contributions and information provided by each actor over time. A green bar, marked with the letter "O", indicates the agenda

point, and the letters "U" and "S" appear at certain moments to signal "Usefulness" and "Positive Stabilization" moments, respectively.

III. RESULTS

In this section, six argumentative episodes, labelled from A to F and extracted from the coordination meetings of SDC BIM 2, were studied. These episodes both question and reveal the sequence of discussions during the BIM coordination sessions and provide an overview of the variety of points discussed in these meetings. They use digital models as the mode of information representation. This section includes the results obtained for the six argumentative episodes, respectively, as well as analyses and discussions of these results.

Episode A took place on 13.03.2020 and concerned group 4. As shown in Figure 7, the discussion aimed to resolve a geometric conflict between an interior wall and a structural beam. A model of the wall in question was created by the BIM modeller responsible for plumbing networks (FL), in order to position toilets and sinks. As shown in the image below, the meeting took place in person, and the conflict in question was displayed on the BIM coordination platform BIMTrack, using a smart board. This mode of presentation was used throughout the whole exchange. The other meeting participants also had access to this conflict and a series of related information via the BIMTrack platform, including the reference number, processing status, models involved and the actors concerned, and could therefore view it simultaneously on their own laptops.

Figure 7. Group 4 BIM coordination meeting during episode A.
Figure 7. Réunion de coordination BIM du groupe 4, lors du déroulement de l'épisode A.

In the results presented in Figures 8 and 9, we observe two phases in the progression of this episode. First, the BIM coordinator primarily led the explanatory discussion of the detected conflict, with six interaction moments involving the structural manager (ST), and HVAC (FL) and envelope (EN) representatives. During this initial phase, we identify a first moment of information adding to the discussion and then a regulation moment leading to useful information for resolving the conflict, such as "remove the wall", "lower the wall", or "extract the wall quantities" expressed as proposals or verifications. In the second part of the discussion, the interior partitioning actor (PI) mainly interacted with the project manager (MOE) to find a collective way to manage this conflict. During this phase, two moments of convergence led to an explicit positive stabilization and useful information for the continuation of the work, following two requests from the PI and a proposal by the MOE to "monitor this conflict throughout the modelling process".

The BIM coordinator made the final decision and formulated a solution: "We will see, once the interior partitioning BIM model (PI) is more advanced, whether we keep the wall modeled by the HVAC manager (FL) or base ourselves on the upcoming interior walls (PI)". The decision on this collective issue is only a provisional solution, and the problem will need to be re-examined later in the project.

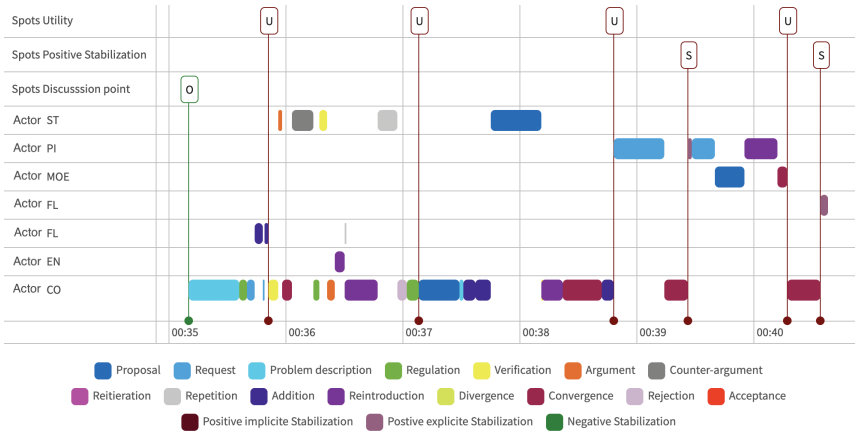

Figure 8. Articulation of verbalization categories in episode A.

Figure 8. Articulation des catégories de verbalisations dans l'épisode A.

Episode B of Group 3 took place on 20.03.2020. As shown in Figure 10, it included the explanation of a series of conflicts that are considered to be of the same type by the BIM coordinator, involving ventilation shafts, interior partitions, and false ceilings, as well as the detailed visualization of one of these conflicts on the BIM coordination platform to provide a concrete example. The conflict illustrated in Figure 12 concerned a non-load-bearing interior partition that was higher than the

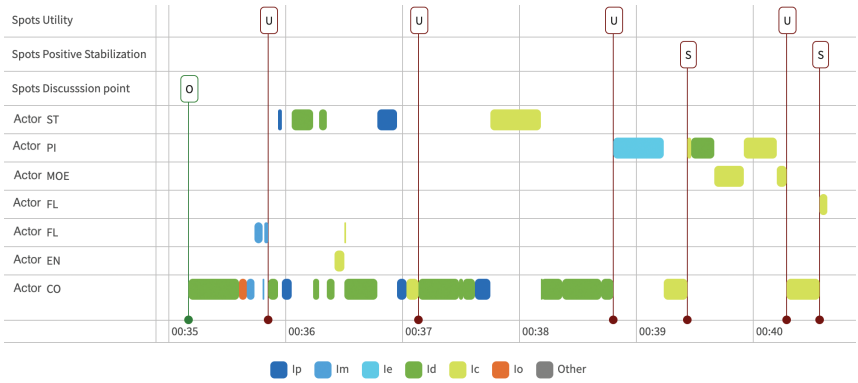

Figure 9. Articulation of information subjects in episode A.
Figure 9. Articulation des objets de l'information dans l'épisode A.

false ceilings, thus representing an incorrect modelling of the upper level of this partition.

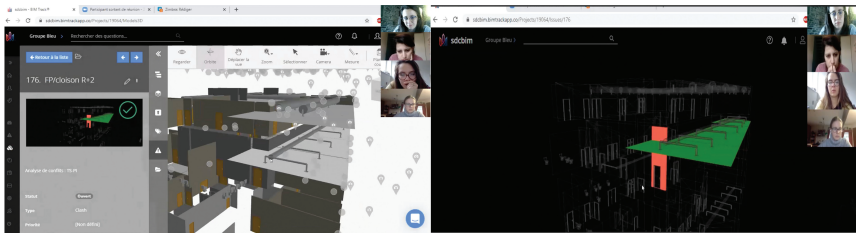

Figure 10. Group 3 BIM coordination meeting during episode B.
Figure 10. Réunion de coordination BIM du groupe 3, lors du déroulement de l'épisode B.

In the results shown in Figures 11 and 12, we observed a discussion initiated by the BIM coordinator based on the number and nature of conflicts between the interior partition models (PI) and the HVAC networks (FL). The interactions primarily occurred between the person responsible for modelling the building interiors (PI) and the person responsible for modelling the HVAC system (FL). After the coordinator briefly described the types of conflicts, and more specifically the situation of the interior wall with the false ceilings, the (PI) actor reiterated the problem, adding a series of details to provide more precision. The (FL) actor requested a better visualization of the conflict in the BIM viewer on the BIM Track platform to better understand the problem. This verification required a series of manipulations and navigation within the BIM model viewer on the platform, with two moments of convergence regarding the geometric understanding of the conflict, using additional viewing angles. Subsequently, the (PI) actor made a proposal after ascertaining that the problem might stem from the tolerances defined in the BIM clash detection tool, providing useful information for the continuation of the

conflict coordination process and leading to a final decision by the BIM coordinator to "not consider the clash and mark it as reviewed." This decision was approved by the (PI) actor.

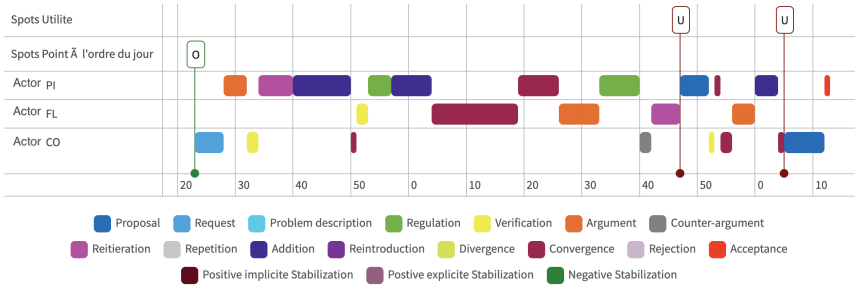

Figure 11. Articulation of verbalization categories in episode B.
Figure 11. Articulation des catégories de verbalisations dans l'épisode B.

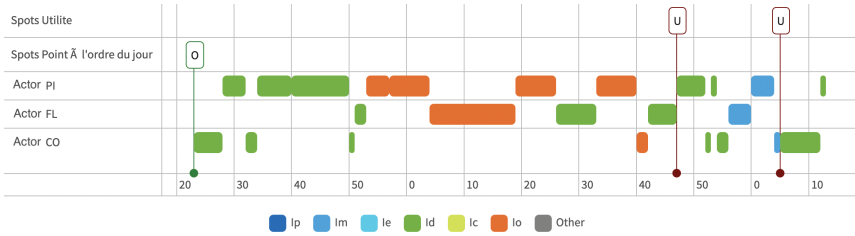

Figure 12. Articulation of information subjects in episode B.
Figure 12. Articulation des objets de l'information dans l'épisode B.

Episode C of group 4 took place on 20.03.2020. As shown in Figure 13, it included a discussion about several conflicts between the structural columns and the external building envelope walls, as well as between the window frames and the columns of this same envelope. Two conflicts were selected to illustrate the discussion, showing multiple overlaps between elements of the envelope and the structure. This episode featured significant interaction between the two coordinators, CO1 and CO2, from the same group, and this deserves further analysis.

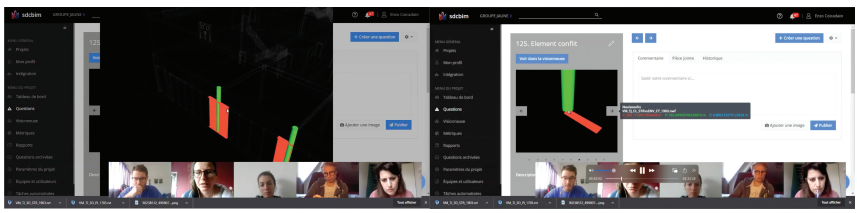

Figure 13. Group 4 BIM coordination meeting of during episode C.
Figure 13. Réunion de coordination BIM du groupe 4, lors du déroulement de l'épisode C.

In the results observed in Figures 14 and 15, we note that coordinator CO1 led the discussion during the first part of the exchange, in which he tried to understand the problem encountered with two verifications and interruptions made by CO2. Then, the envelope manager (EN) added detailed explanations of the conflict in terms of the sizing of the elements involved, specifically the doubled 40 cm columns in a model provided by the structure manager (ST), followed by additional information on identifying the window frames in question, for which he provided a model.

The second part of the exchange between the project manager (MOE) and the envelope manager (EN) focused on the design of this construction node, followed by a useful proposal from the MOE regarding modelling adaptations, summarized as "[a reduction of] the cross-section of the columns to align with the thickness of the concrete wall of the envelope". A subsequent proposal and negotiation concerned the adaptation work to be carried out later in the BIM models (EN) and (ST), which led to the conclusion that "If it's the exterior walls, it is the responsibility of the envelope modeller to ajust them, and the structure team must remove their modeled elements."

Coordinator CO1 enforced the BIM modelling protocol defined beforehand by all project actors collectively by reminding everyone that "the envelope manager models everything on the building's exterior", including the structure of the envelope. In this case, this reminder was considered the useful information for the continuation of the work, which was explicitly accepted by CO2 and implicitly accepted by all others.

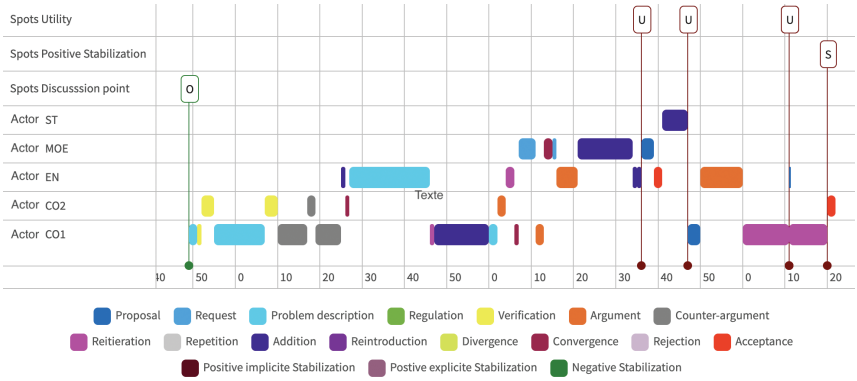

Figure 14. Articulation of verbalization categories in episode C.
Figure 14. Articulation des catégories de verbalisations dans l'épisode C.

Episode D of Group 3 took place on 27.03.2020. As shown in Figure 16, the participants discussed the issues related to the passage of ventilation ducts through the structural mesh within the building floors. Several conflicts posed problems, firstly, because they were not detected by the BIM clash detection tool, and secondly, because a suitable modelling solution was needed to properly route the ducts through the mesh.

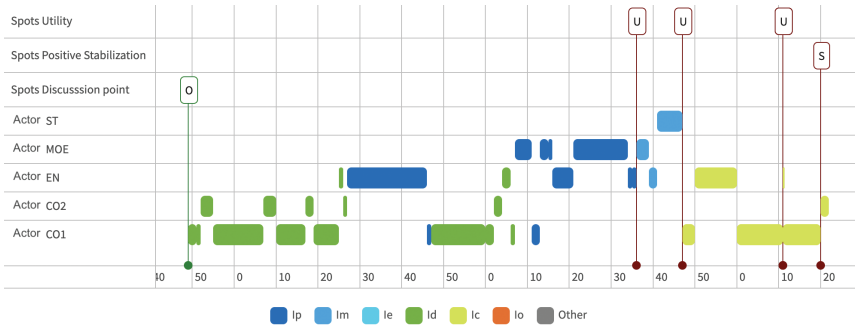

Figure 15. Articulation of information subjects in Episode C.
Figure 15. Articulation des objets de l'information dans l'épisode C.

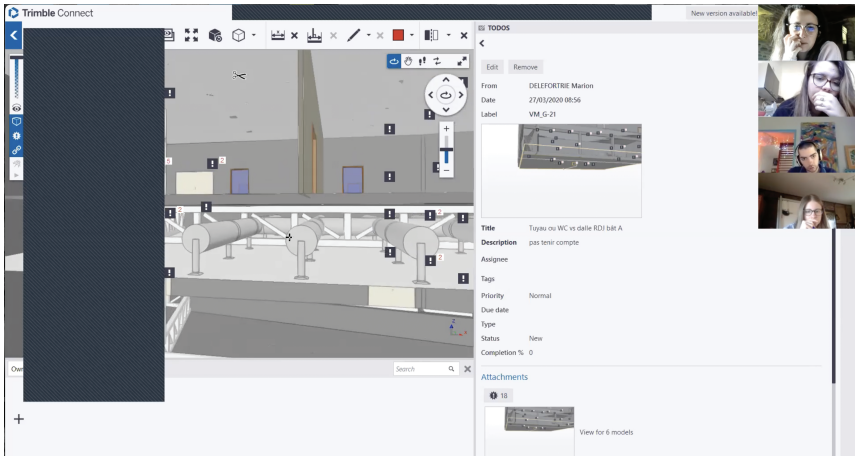

Figure 16. Group 3 BIM coordination meeting in Episode D.
Figure 16. Réunion de coordination BIM du groupe 3, lors du déroulement de l'épisode D.

In the results observed in Figures 17 and 18, we note that CO1 explained the agenda item but admitted a lack of knowledge regarding the BIM coordination tool for conflict detection and was unable to diagnose the problem. Meanwhile, the network (FL) and structure (ST) managers tried to coordinate efforts, focusing on the dimensions of the modelled elements. The MOE requested a section cut in the building to better visualize the problem encountered. The visualization of this section led to numerous interactions between the FL, ST and MOE, resulting in a first convergence, followed by a detailed explanation from the ST manager about the need to revise the modelling of certain ventilation duct sections, while the MOE wanted the pipes to just fit through the triangulations of the truss. Despite CO1's counter-argument, a second convergence emerged between the MOE and FL manager, leading to a proposal by CO2 to "use the IFC structure model to remodel the pipes in the floor" in order to

correctly integrate the ducts in the right locations. This information was useful for the continuation of the modelling process and the resolution of these conflicts. A series of useful and operational information flowed from this, such as "we need to look at building C", "I have to shift everything, remove the ducts and reposition them more regularly", and "you need to space them according to the truss to position them in the right places". CO2 actively participated in the search for a solution and in the final decision-making, whereas CO1 slowed down the search for solutions citing a lack of knowledge of the BIM conflict detection tool or underestimating the importance of the conflicts. The coordinator's profile seems to play a crucial role in reaching a collective solution.

Figure 17. Articulation of verbalization categories in Episode D.
Figure 17. Articulation des catégories de verbalisations dans l'épisode D.

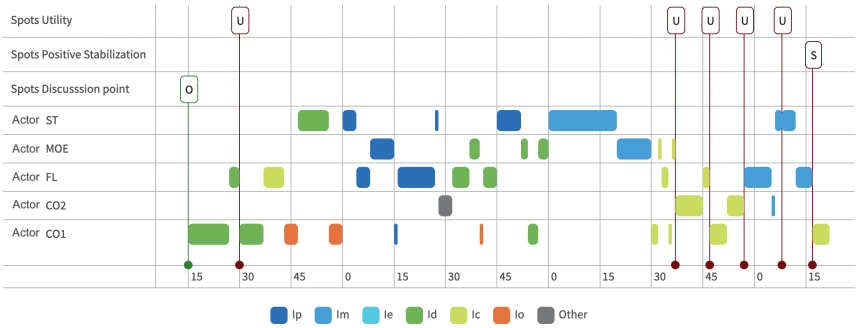

Figure 18. Articulation of information subjects in Episode D.
Figure 18. Articulation des objets de l'information dans l'épisode C.

Episode E of Group 4 took place on 27.03.2020. As shown in Figure 19, all project actors, except the (FL) manager, participated in this

discussion about glazed bays clashing with the structural beams of the façade.

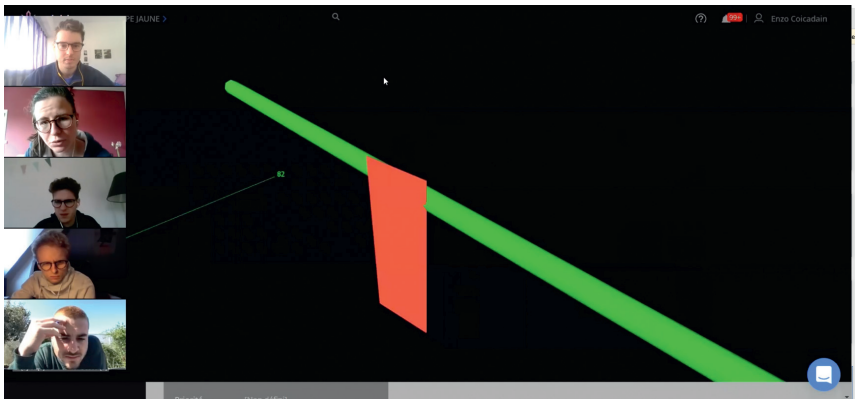

Figure 19. Group 4 BIM coordination meeting in episode E.
Figure 19. Réunion de coordination BIM du groupe 4, lors du déroulement de l'épisode F.

In the data observed in Figures 20 and 21, we note a first phase of the episode where CO1 led the discussion, with very brief interactions with the other actors, by describing the conflict problem, verifying it, regulating it and finally proposing the following solution for the continuation of the modelling work: "the trusses need to be shifted slightly because it is not the envelope's modeller responsibility to move the glazing". This information is useful but the proposal is not feasible in the long term due to the difficulty of its application, leading the MOE to make a counter-proposal of a model shifting the glazing plan, which was immediately accepted by both the EN responsible and CO1. The ST responsible then explained the reason for the misalignment between the glazing plan and the beam axis. A second acceptance by CO2 was expressed with the words, "Yes, you're right, we will shift the envelope". This was followed by a phase of questioning by CO1 regarding the presence of a false ceiling in that area and the design of this construction node, such as the ceiling height, position of the false ceiling relative to the window, floor slab and the glass layout. Two solutions were proposed by the PI and CO1, with the PI's solution being counter-argued by CO1, and convergence occurring around CO1's proposal when the EN responsible validated the need to "redefine the envelope wall with its glass as a single component", thus changing its modelling method. Finally, the episode concluded with a final validation of this decision by CO2.

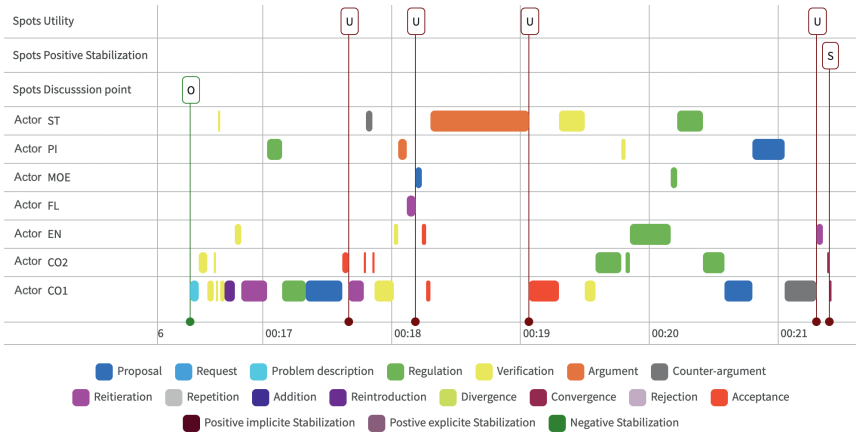

Figure 20. Articulation of verbalization categories in Episode E.
Figure 20. Articulation des catégories de verbalisations dans l'épisode E.

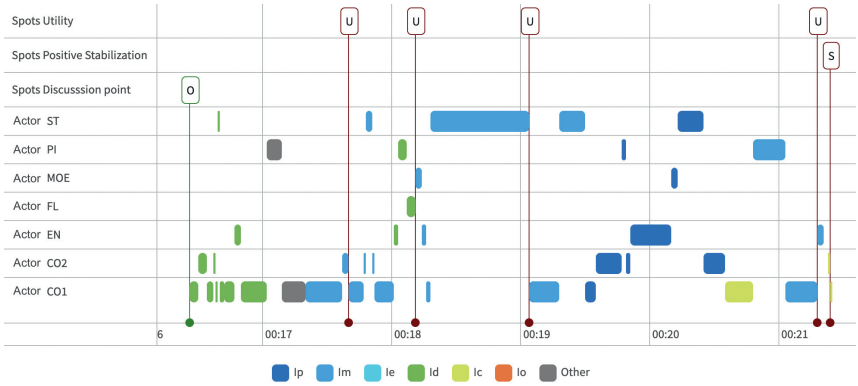

Figure 21. Articulation of information subjects in Episode E.
Figure 21. Articulation des objets de l'information dans l'épisode E.

Episode F of Group 4 took place on 27.03.2020. The topic addressed the layout of the windows, specifically those positioned in front of slabs and interior walls.

As shown in Figures 22 and 23, we observed a first phase in which CO1 described the conflict, and asked which BIM modeller would correct the model: either the structural manager by shifting their slabs or the envelope manager by moving the windows. CO2 argued that it was impossible to move the slabs in the structural model. A second issue arose regarding the possibility of moving the facade windows, given the existing layout. The MOE proposed moving the windows in the envelope model, and this useful information appeared to be crucial for the continuation of the window modelling process. Next, the example of the collision between

an interior wall and a window was discussed. Several arguments led to the managers responsible (ST) and (EN) discussing who would need to further correct the model. The abovementioned proposal to move the windows was put forward once again and was accepted by the group.

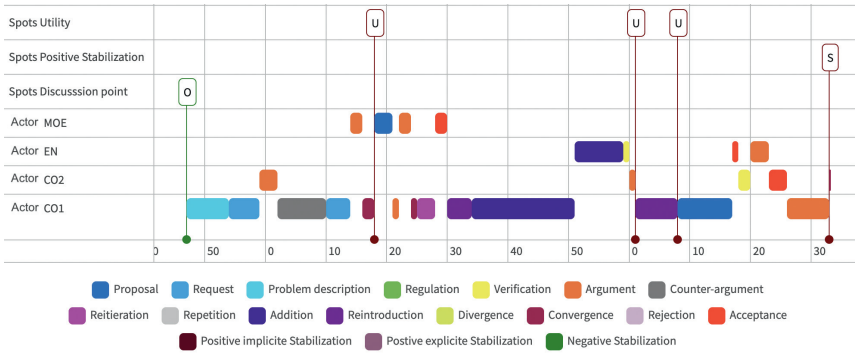

Figure 22. Articulation of Verbalization Categories in Episode F.
Figure 22. Articulation des catégories de verbalisations dans l'épisode F.

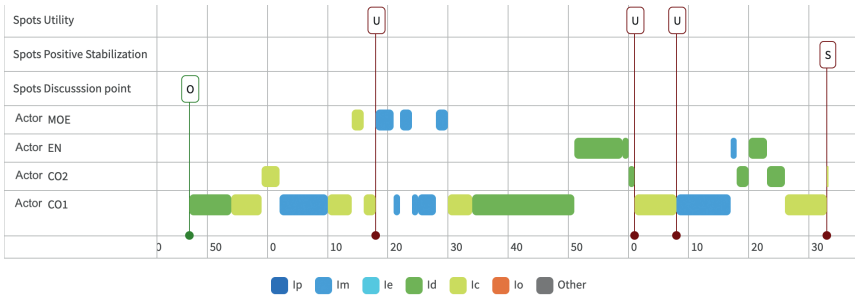

Figure 23. Articulation of Information subjects in Episode F.
Figure 23. Articulation des objets de l'information dans l'épisode F.

IV. CONCLUSIONS

Several observations emerged from our results of our analysis. First, the actors CO1 and CO2 consistently made "Proposals" and put forward "Arguments". Moments of "Verification" were quite brief in all episodes, and instances of "Divergence" were non-existent. Moments of counter-argumentation were also rare. The role of the BIM coordinators appeared crucial in reaching convergences and collective decision-making, with their verbalizations taking up a significant part of all observed episodes.

Several elements were observed that should be recommended for future BIM coordinators and BIM training. For example, coordinators should propose provisional solutions to problems during coordination meetings, which can then be reevaluated later in the collaborative process. They should ensure the best visualization of a discussed conflict; hence, coordinators need to develop strong proficiency in BIM software to detect conflicts and monitor their resolution processes. Furthermore, coordinators should leverage their professional experience, technical background and construction site knowledge to assess the importance of conflicts and problems discussed in coordination meetings, in relation to the overall project process and/or actual issues encountered on-site. They should also ensure compliance with collective decisions made upstream in the process, within the BIM exchange protocol or modelling agreements, and implement methodical quality checks of BIM models by anticipating collaborative decision-making moments. The BIM coordinator should adopt a constructive attitude rather than hindering the collective search for solutions, in order to negotiate intelligent, priority modifications to models with project actors in response to detected issues. This role is also strategic for distributing tasks and monitoring the work of BIM modellers across disciplines, as well as reminding project actors of their responsibilities and shared final objectives throughout the project. Finally, it is essential that the BIM coordinator understands the technical and architectural design of the project to propose improvements or solutions to conflicts that consider the project's reality. They must avoid being a passive "external" observer to debates; indeed, although their main role as a "problem describer" remains essential, they can advance collective reflection by asking the right questions to the right people or to the entire work group at the right time.

Useful information most often takes the form of "proposals", which mainly concern digital modelling and the organization of collective work. In several episodes, convergences help formulate operationally useful verbal information.Useful information usually requires several verbalizations before an answer to the question or problem is found, and it is therefore not an immediate solution. Nevertheless, it is often crucial for the continuation of the collaborative modelling process and group work organization. It provides both short-term benefits, for instance, enabling convergence towards a solution in coordination meetings and closing agenda points, and long-term benefits for the coordination process and workflow when decisions made in meetings are implemented effectively later in the project.

The role of the MOE (project manager) is critical at key moments to help other actors make decisions or adopt solutions. Their ability to make rapid decisions in negotiation situations influences the flow of exchanges in BIM coordination meetings, making their presence very important. Their comprehensive knowledge of the construction project and the "Ip" category often facilitates decision-making in conflicts encountered during building modelling. This project knowledge or lack of design information is characteristic of the project architect and is gradually shared with all project actors as BIM coordination meetings progress.

Our episodes focus on exchanges occurring during the use of the digital model as a mode of information presentation, but other modes of representation may also coexist with it in some coordination meetings. Additional episodes could be studied to complement our observations. We also note repeated reminders by BIM coordinators to their teams to adhere to procedures already defined in other BIM tools or documents, such as the BIM protocol. Future work will focus on analysing such protocols, which predefine and influence the management of information exchanges, collaborative modelling and coordination processes of various digital models. The main limitation of our study was the participation of students in an experimental setting. In the future, it would be interesting to study collaboration activities using the same tool in a real work context, such as a construction company. Nevertheless, this study has the advantage of describing the detailed process of solution development and how the Common Tools software is used for this purpose. It would be relevant to further explore how projects can be managed in the future using this tool to provide insights for improving collaboration situations and/or the collaborative process.

Ethics

We clearly and comprehensively informed participants in the BIM experiments about the objectives, methods, potential risks and benefits, as well as their right to withdraw at any time. Informed consent was duly obtained. All data were anonymized and securely stored. The results are disseminated responsibly, with findings published transparently-without manipulation or intentional omission of data-while respecting intellectual property rights and properly citing all sources.

Conflicts of interests

The authors declare that no financial or scientific conflict of interest influenced the work presented in this article.

Authors' contributions

A. Rahhal – Conceptualization, methodology development, formal analysis, data coding, data visualization and presentation, statistical analyses, and writing

S. Ben Rajeb – Study supervision

P. Leclercq – Study supervision, provision of the "Common tools" software, and funding

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Manuscrit reçu / Received: Novembre 2024/ November 2024
Accepté après révision par /Accepted by Guillaume Gronier & Gaelle Baudoux: Mai 2025/ May 2025