MÉMOIRE DE MASTER DESIGN GLOBAL SPÉCIALITÉ « ARCHITECTURE MODÉLISATION ENVIRONNEMENT »

SYNCHRONOUS COLLABORATION AND 3D INTERACTIONS

AEC INDUSTRY IMPLEMENTATION

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“Individually, we are one drop. Together, we are an ocean.”

Ryunosuke Satoro

ABSTRACT

Digitalization, modernization, innovation, interconnection, globalization – all these tendencies create some dynamics of the contemporary architecture, engineering, and business methods evolution.

New technologies and devices offer an access to the new amount of possibilities and capacities, but with the new technology arise there is always a commitment for a new method of the technologies application, and for the integration into the existing practices and purposes.

This research aims to study the existing technology of interactive collaboration environments to relieve the technology advantages for the educational and professional uses in architecture, engineering, and construction domain, and to propose some improvement possibilities for the existing methods of collaboration of the architecture projects development.

ACKNOWLEDGEMENTS

I would like to express my gratitude to MAP-CRAI laboratory for an opportunity of doing the research internship. And, I'm very grateful to my supervisors Gilles Halin and Pascal Humbert, who always believed in my potential, thank you very much for your guidance, help, support and encouragement. Also, I'm very thankful to the head of the AME masters study program Damien Hanser for the rewarding schoolyear and the intern position recommendations.

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CONTENTS

INTRODUCTION

The generation of pioneers in digital architecture has prepared some theoretical and practical digital basis through the numerous experimentations. But the current generation suffers from the lack of methodology of the digital tool practice. And yet, the extended 3d models and BIM practices have been already integrated into the project development process by many professionals.

But the projects done with the integration of these tools have the gain in modeling, exchanges, and communication around the project, as well as the development coordination inside the project. These new aspects are appealing to some significant changes in the work methods and practices, and, surely, increase some new complexity to the project.

The complexity leads to the efficient methods development for collaboration and exchanges, of representation, visualization, discussion, and decision making. The next progress step will be towards the BIM methods, which will question the current methods of collaboration and the project conception exercise.

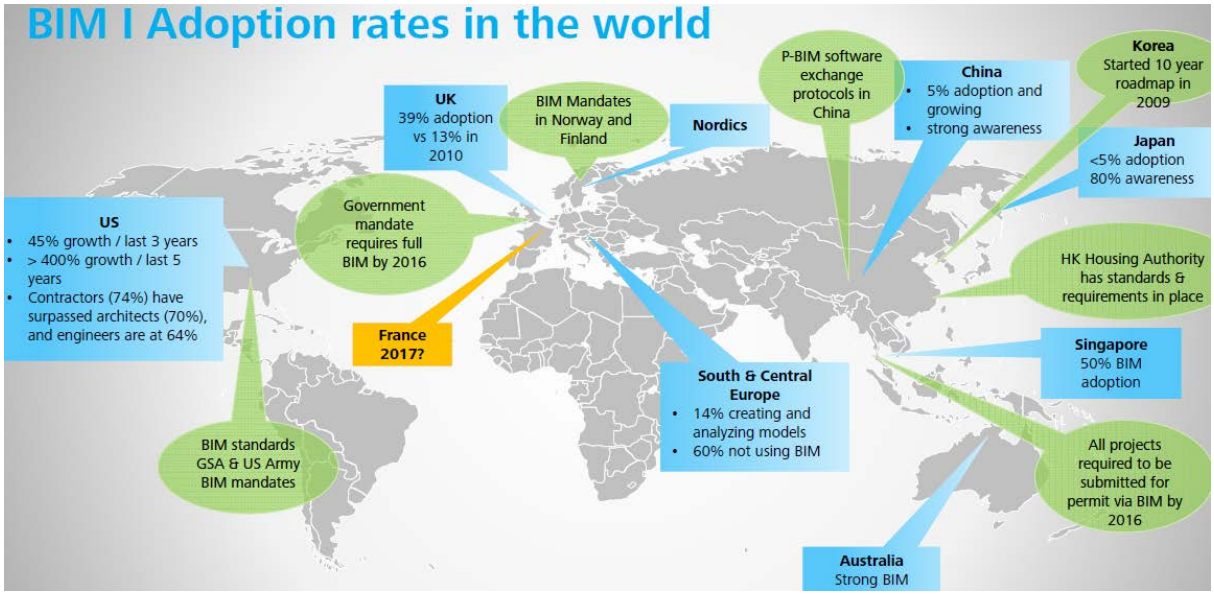
1. STATE OF ART

1.1. DIGITAL ERA AND BIM. AEC INDUSTRY BACKGROUND.

The practice of architecture has changed over the last decades. Nowadays, most of the Architecture Engineering Construction (AEC) professionals develop their projects with a help and an active use of the digital Computer Aided Design CAD[1] methods. The methods usually expressing and visualizing the project development not only with the 2D drawings, as it was common for the predigital era, but also with a virtual 3D model.

The aim of perfection and efficiency increase are progressively evaluating the AEC practices and methods towards the BIM[2] methods of the project development. The statistics of the changes is quite impressive, all over the world the AEC professionals are emerging BIM practices. (Figure 1).

Figure 1. BIM adoption rates in the world based on results of National BIM Report 2013 from NBIS. (Di Giacomo, 2015)



[1] CAD, or computer-aided design and drafting (CADD), is the use of computer technology for design and design documentation. CAD software replaces manual drafting with an automated process. p.21 (Celnik et al., 2014)

[2] The BIM is an integrated way of working, allowing the design, execution, and management of Buildings and real estate. p.37(Celnik et al., 2014)

The BIM method concept doesn't contain only one type of data but gathers it around a virtual building 3D model, completing it with the new layers of project information (parametric, sharing, exchanges, execution, global and precise details, etc.). All these data have links with the different project phases and with the different contractors, but its gathered to present a result as a digital model, so BIM practices permit to collaborate around it. And the data is gather form the different disciplines, which is one of the main advantages of the method. (Abuelmaatti and Ahmed, 2010).

But apart the technical contents of the project there is a social collaborative part of the project development strategy. The technical core prepares the data and the work tools of the project for the collaborative manipulations, meanwhile the actual project progress depends on a quality of the technical and the social parts of the prosses, where the synchronous collaboration plays a role of the first social core related scale field to operate the project and creates the work field for the further larger scale of practices. (Figure 2).

Such a collaborative approach requires a modernization and a reorganization of the project development process algorithm, and a change of the approach philosophy. Where the common project development aim is not separated from the tasks an information development level. A connected project development keeps a project information under the same data storage and representation interface. (Figure 3)(Kvan, 1998).

Figure 2. BIM sociotechnical system. (Hong Kong Building Information Modeling Institute).

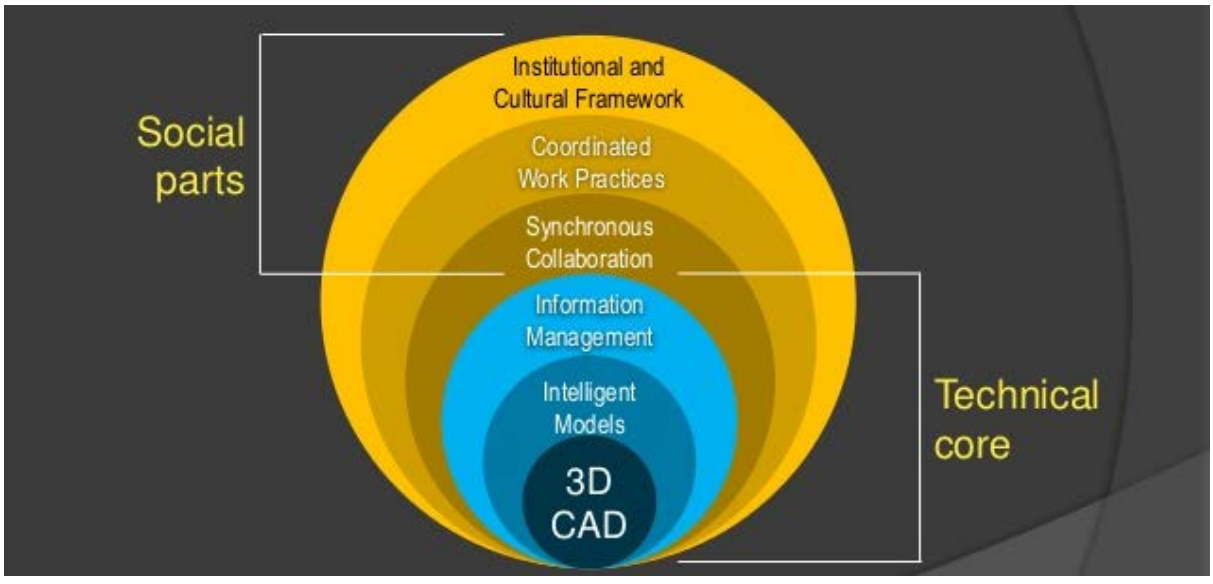
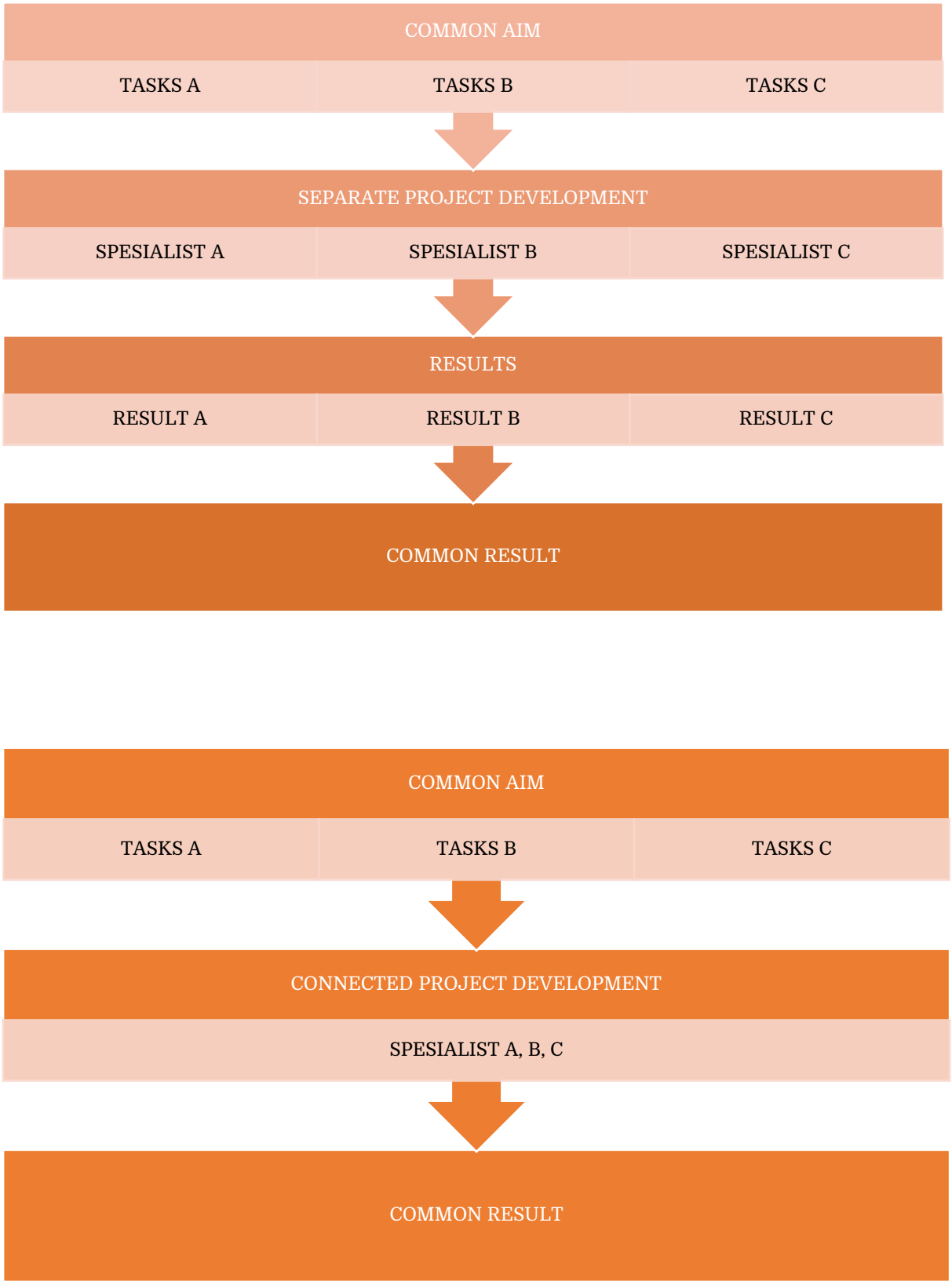


Figure 3. Collaborative development approaches without a shared collaborative environment implementation (top) and with one (down).

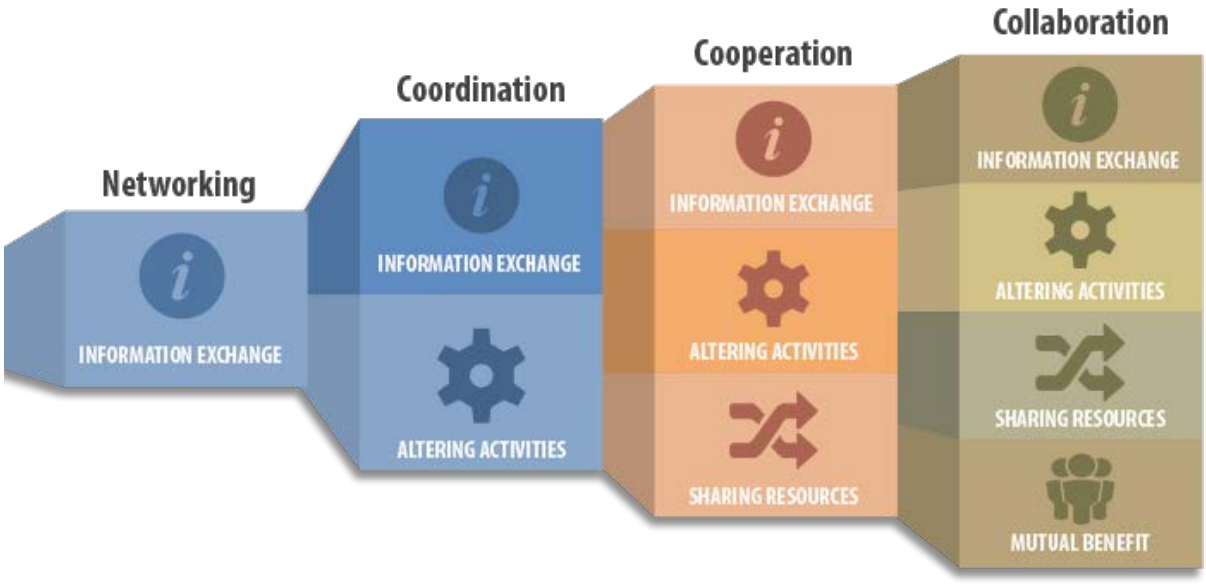


1.2. COLLABORATION DEFINITION.

Arthur Himmelman has developed a collaborative continuum concept (Himmelman, 2004) to describe the different ways of working together between the discipline professionals and different project developers. The concept of continuum includes: networking, coordination, cooperation, and collaboration. (Figure 4).

The representation is based on a level system, where the evolution and complexity are following the levels along the continuum. The level importance (and complexity) involves a change of the strategy used and vary on the aim. There are greater levels of trust, time, and turf committed in the relationship as you move up through the continuum. (Himmelman, 2004).

Figure 4. Himmelman's Collaborative Continuum. 2002. (Toolkit2Collaborate, 2010).



- NETWORKING - exchanging information for mutual benefit. Networking is the most informal of the inter-organizational linkages and often reflects an initial level of trust, limited time availability, and a reluctance to share turf.

- COORDINATING - exchanging information and altering activities for mutual benefit and to achieve a common purpose. Coordinating requires more organizational involvement than networking and is a very crucial change strategy. Coordinated services are "user-friendly" and eliminate or reduce barriers for those seeking access

to them. Compared to networking, coordinating involves more time, higher levels of trust yet little or no access to each other's turf.

- COOPERATING - exchanging information, altering activities, and sharing resources for mutual benefit and to achieve a common purpose. Cooperating requires greater organizational commitments than networking or coordinating and, in some cases, may involve written (perhaps, even legal) agreements. Shared resources can encompass a variety of human, financial, and technical contributions, including knowledge, staffing, physical property, access to people, money, and others. Cooperating can require a substantial amount of time, high levels of trust, and significant access to each other's turf.

- COLLABORATING - exchanging information, altering activities, sharing resources, and enhancing the capacity of another for mutual benefit and to achieve a common purpose. (Himmelman, 2004).

Such a gradation arranged in the continuum gives a clear vision of the interactions role and the value of the actions. Nevertheless, there is no one opinion which defines the collaboration and cooperation differences, but a number of various definitions, so the terms meaning should be noted. In this research the Himmelman's definition is taken as a term definition.

1.3. DIGITAL COLLABORATION.

Computer mediated communication (CMC) and computer supported cooperative work (CSCW) research areas are covering the studies and innovations of the collaborative technologies development and practice implementations.(Ming and Hovard, 2004) .

Collaboration is an activity - not a piece of technology.(Charlesworth et al., 2003) .

Collaboration type and style depend also on the combinations of software/hardware employed to help people collaborate:

- Enterprise portals
- Intranet
- Generic workspace
- Project team applications
- web/video conferencing
- Online meeting applications
- Peer-to-peer file-sharing
- Real-time instant messaging
- People that collaborate, not technologies or systems!

Collaboration involves all the users into the same interface, in to the shared environment where processes and information can be efficiently and effectively integrated into the project development process. Paul Wilkinson in his book “Construction Collaboration Technologies: The Extranet Evolution” proposes a resume of the classifications of the collaborative interactive technologies by the number of specialists. Most of the authors choose the two main classes of the collaboration: synchronous and asynchronous, and adjust the to the users positioning per each other. (Wilkinson, 2005) (Table 1).

With the development of technologies, the time and place of the communicators had less of the meaning for the classification, but the aim and a type of the work exchanges led to the resume of a communication, cooperating and collaboration technologies.

Table 1. Classifications of interactive technologies (Wilkinson, 2005).

STUDIES	TECHNOLOGIES
Coleman (1997)	• Synchronous (desktop and real-time data conferencing, electronic display, video conferencing and audio conferencing) • Asynchronous applications (e-mail, bulletin boards, non-real-time database sharing and conferencing, workflow applications)
Duarte & Snyder (1999)	• Same time, same place (residence meeting) • Same time, different place (audio conference, video conference) • Different time, same place (chat room, bulletin board) • Different time, different place (e-mailing, voice mail message)
Bonk, Medury, & Reynolds (1994)	• Electronic mail and delayed messaging tools • Remote access/Delayed collaborative writing • Real-time dialoguing and idea generation tools • Real-time collaborative writing tools • Cooperative hypermedia
Chinowsky & Rojas (2003)	• Communication technology • Cooperation technology • Collaboration technology

Historically the essential functions of communication technologies: message exchange and information delivery. But the cooperative technologies feature technical advances over communication technologies. So nowadays the main purposes of collaboration technologies are to provide real-world work situations and experiences(Guerriero and Gronier, 2014).

Collaborative interactive technologies have their own specific features (Table 2), which correspond to the needs and the specifics of the work process. In the case of the AEC work sessions the collaborative technology would be the one for decisions making sessions and has the closest profile to the actual common project development and discussion meetings scenarios.

Table 2. Comparison of different interactive technologies. (Wilkinson, 2005).

TECHNOLOGIES	FEATURES	CHALLENGES
Communication technology	• Analog devices • Access available at any time • Easy to use • Familiar functions • Impersonal media • Ambiguity of text messages (email)	• Asynchronous electronic communications • Synchronous analog communications • Heavily depend upon information transmission • Limited access to archived information and conversations • Limited communicational clues and contexts
Cooperation technology	• Able to support various instructional activities • Allowing time to reflect and elaborate thinking • Effective to avoid repetitive questions through email • Impersonal media • Ambiguity of text messages	• Time delay due to asynchronicity • Limited communicational clues and contexts • Needed for detailed planning for function specification
Collaboration technology	• Real-time exchanging opinions • Prompt feedback • Providing high contextual clues • Prompting dual coding of information • Possible to be distracted	• Work awareness information required • Information on teamwork progress required

All the technologies find their use and advantages for the project development interactions between the discipline specialists. The cooperative technology would correspond to the methodological tools of the meeting setups and meeting feedback processes. And the communication technology plays the usual role of a simple information distribution and reception (Guerriero and Gronier, 2014).

1.4. COLLABORATIVE RESEARCH EXPERIENCES.

Many researches have been developing the digital collaboration scenarios and workspaces. Following resume contains the examples of the different types of the workspaces.

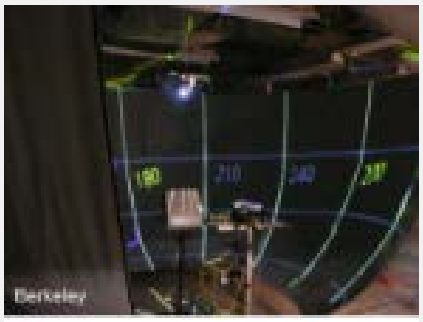
Table 3. Collaborative work spaces research examples.

RESEARCH	TECHNOLOGY PROPOSITION	
FUTURE SCENARIO FOR A COLLABORATIVE DESIGN SESSION (ACHEN, 2001).	Active Worlds 3-dimensional Web Universe http://www.aw-europe.com/ The 2D-desktop will be replaced by a 3D-environment. • The appearance of the 3D-environment changes with the purpose of the user, just like a different social event in real life usually is conducted in a different setting. • For each project, the designer constructs a personality, which is an assembly of skills (software) and appearance (avatar).	
HOLODESK: DIRECT 3D INTERACTIONS WITH A SITUATED SEE-THROUGH DISPLAY (HILLIGES ET AL., 2012)	• Proposes to use a 3d virtual reality to cooperation work as it represents the idea of cooperation graphically. In a normal office workspace, nowadays it is not represented.	

COMPARING IMMERSION IN COLLABORATIVE IDEATION THROUGH DESIGN CONVERSATIONS, WORKLOAD AND EXPERIENCE (DORTA AND KALAY, 2011)

2d exchange sketching is possible by web but limited the same way the real sketching is.

- Designers are not in touch with life-size-representations,
  deceived by the proportions of space and shapes, sketching distorted perspective views for lack of graphical references, limited by the 2D representational frame (screen or projection). So, the life-size immersive freehand sketches and physical models for local and remote collaboration to remote collaboration in design. Design conversations patterns (CI-Loop, CC, and CM) the NASA TLX for workload.

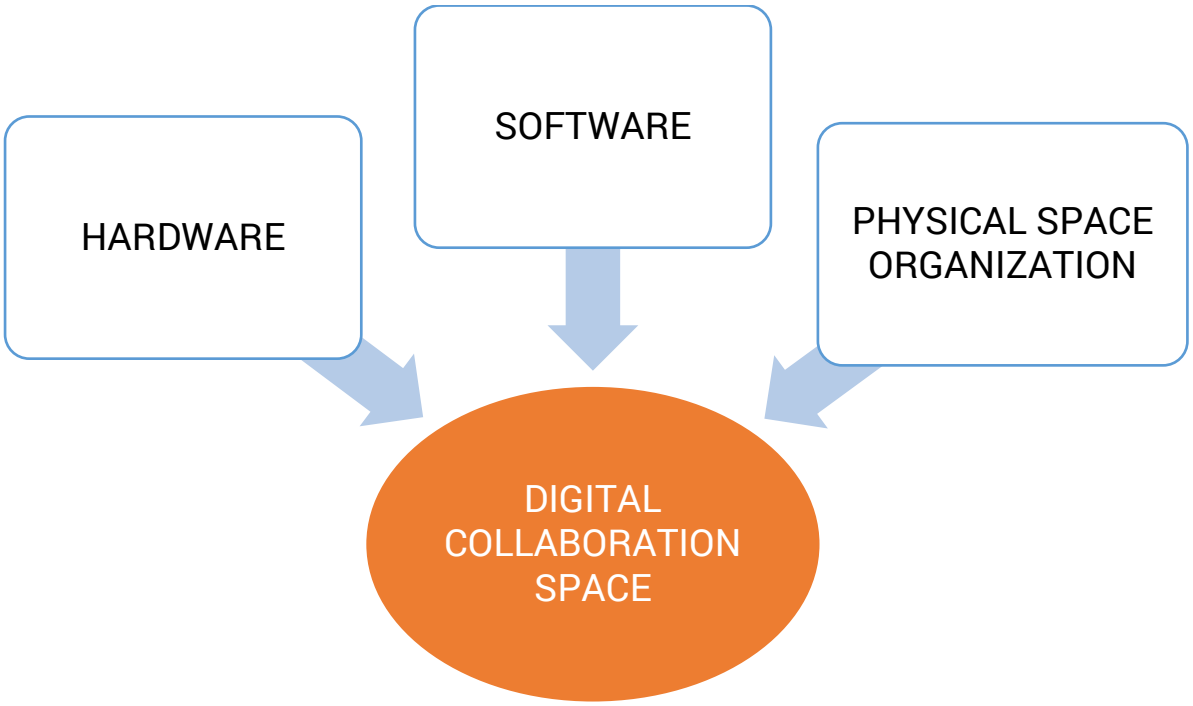


TOWARDS A NEW REPRESENTATIONAL ECOSYSTEM FOR THE DESIGN STUDIO(DORTA AND KINAYOGLU, 2014)

The Hybrid Ideation Space (HIS) used in the Augmented Design Studio, is a design environment that allows digital and analog representations to enhance each other. The HIS immersive projection system consists of a 5m diameter, 360° semi-spherical display for immersive visualization, and dedicated software that allows for intuitive manipulation by immersive sketching and model making.

2. DIGITAL COLLABORATION WORKSPACE (DCW) AT MAP-CRAI.

Figure 5. Digital collaboration space quality factors.



In order to continue the research on the digital collaboration MAP-CRAI has installed the digital collaboration workspace at the laboratory, in a partnership with the Immersion company. DCW has rather custom characteristics, aiming the research for the digital collaborative technologies and methods for the AEC sector, but also contains some basic contents and tools of the Immersion products (Shariiing software, multi-touch screen technology).

Any digital collaboration space should rely on several criterias to assure an efficient performance. Thus, the system's hardware and software should provide all the performance capacities, and by the physical space qualities (Figure 5).

1.5. "IMMERSION" COMPANY.

The French company Immersion develops a variety of products and gadgets for digitalization of creativity and collaboration processes in business, representation and interaction of the virtual reality, "*…player in innovative, immersive and collaborative 3D technologies, in the fields of industry and research.*" (Immersion company, n.d.).

The Meetiiim was developed by Immersion as a digital synchronous collaboration device (Figure 6), which is composed of the table within integrated horizontal touch screen connected to the computer with the Shariiing software installed (Figure 7).

The Shariiing is a software dedicated to create a digital environment for a synchronous collaborative work. The software's main functions are to display and interact with the work session documents uniting them within the digital collaboration environment.

Figure 6. Meetiiim by IMMERSION.(Immersion company, n.d.)

Figure 7. Shots from the official Shariiing by Immersion promo video – Immersion3D official YouTube channel.(Immersion3D, 2015).

1.6. DCW TECHNICAL SPECIFICATIONS.

Digital collaboration workspace (DCW) has two computer systems “Wall” and “Table” (Figure 10), which are connected to the same local network. The Wall’s vertical display surface is a LCD screen of 98” from Planar Ultra Res Touch series which is a series of the 4K Interactive LCD Displays. The display has 32 touch points and offers a high quality of the image in 4K with a standard resolution of 3840*2160. The multi-user technology gives an access to the multiple users to collaborate and interact at the same time. This kind of a display’s advantage for the professionals who seek to collaborate or annotate is in the large viewing area and the highest image resolution.(Planar, 2014). The display lowest point is at the height of 1.2 meters to maximize an access area of the screen for the manipulations.

The performance of the computer system is provided by the components with some well adapted technical characteristics. The HP Z440 Workstation with the Intel(R) Xeon(R) CPU E5-1650 v3 3.50 GHz processor, 32 GB of RAM and NVIDIA Quadro K5200 8GB graphics card. Such contents assure a high performance and a support of the touch technology, high quality graphics and immersive experiences.

The Wall’s vertical display surface is a LCD screen of 98” from Planar Ultra Res Touch series which is a series of the 4K Interactive LCD Displays. The display has 32 touch points and offers a high quality of the image in 4K with a standard resolution of 3840*2160. The multi-user technology gives an access to the multiple users to collaborate and interact at the same time (Figure 11). This kind of a display’s advantage for the professionals, who seek to collaborate or annotate, is in the large viewing area and the highest image resolution. (Planar, 2014).

Furthermore, the Wall is equipped with a V120 Trio system of the motion tracking. So, three 6DoF cameras are integrated into the tracking bar device, “self-contained and factory calibrated”, “Operate a camera in IR grayscale mode for high-speed reference video. Visible spectrum video is also available in the center camera”,(Optitrak, n.d.) with a possibility of synchronization with external devices, like the 3D shutter glasses.

To complete the motion tracking system, the user movements are captured form the optical tracking targets: Senso (Light and Shadows company, n.d.) and 3D passive glasses (Figure 8). The hole system recognizes the user's movements and gives an immersive experience to the user, adapting the VR model to the tracked motions (Figure 9).

Figure 8. Senso and Glasses optical tracking targets.

Figure 9. Wall system – motion tracking cameras, 4k screen, Senso, 3d glasses with some optical tracking targets.

The “Table” has some like “Wall” hardware parameters but with a different graphics card NVIDIA Quadro K5000 4GB. The display was integrated into a custom designed and a custom made wooden table. The screen is a Toshiba TV with a resolution of 1920x1080 and an active 3D image support. (Figure 12). The touch option was added with a plug-in of an infra-red frame from PQ labs. The frame is placed on the top of a glass covering the TV, and it allows to receive a maximum of 32 touch points positions. The technology stays for a moment relatively expensive for the budget of a small AEC firms, but the technology development is in progress and the diminution of costs is a matter of time. (Table 4).

Table 4. Technical specifications of the DSCS displays.

	WALL	TABLE
DISPLAYS	Planar Ultra Res Touch	Toshiba TV
SURFACE TYPE	Vertical	Horizontal
SCREEN	Planar UR9851 Touch	Toshiba
SIZE	98”	46” smart 3D
RESOLUTION	3840*2160 4K	1920*1080 HD
TECHNOLOGY	LCD	LCD
3D OPTION	Passive 3D	Active 3D
SCREEN PRICE	27 000	450
TOUCH FRAME	PQ Labs	PQ Labs
FRAME PRICE	Screen price included	740
COMPUTER		
MODEL	HP Z440 Workstation	HP Z440 Workstation
PROCESSOR	Intel(R) Xeon(R) CPU E5-1650 v3 3.50	Intel(R) Xeon(R) CPU E5-1650 v3 3.50
RAM	32 GB	32 GB
GRAPHICS CARD	NVIDIA Quadro K5200 8GB	NVIDIA Quadro K5000 4GB
OPERATION SYSTEM	Windows 10	Windows 10
ADDITIONAL GADGETS	Keyboard, mouse	Keyboard, mouse
PRICE	3000	3000
SHARIIING LICENCE	7500	free

Figure 10. Digital synchronous collaboration workspace at MAP-CRAI.

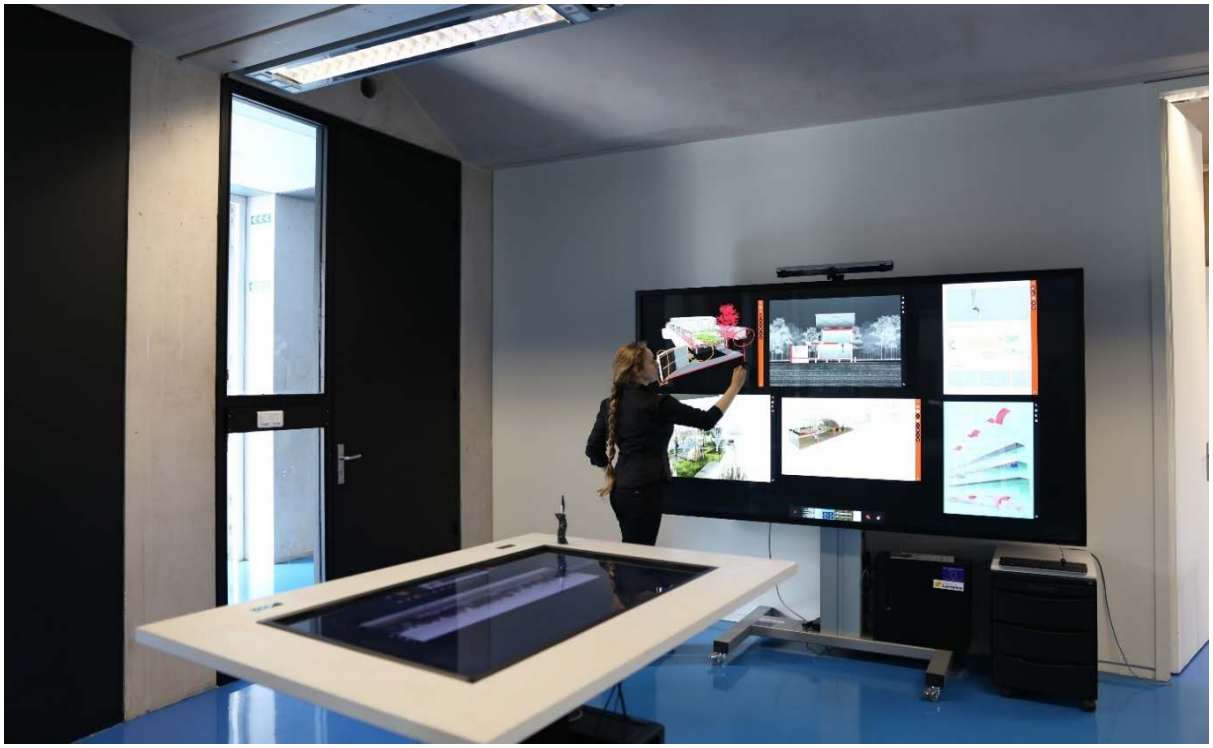


Figure 11. The Wall with Shariiing in use by two architecture students. (on the left). The Table with Shariiing in use by architecture students. (on the right).

Figure 12. The Table.

1.7. SHARIIING SOFTWARE KEY FEATURES.

AEC project development involves a team work for certain number of various professionals. In general, the ways of the development depend on the domain, but the need to share, discuss and integrate results of their work and advancement. So, the same collaborative work environment could untie all the results to make easier the exchanges and interactions.

Shariiing unites all the information for a synchronous collaborative work session at the same digital work environment, which gives the united work area and work gesture-manipulation for the documents. Shariiing software is compatible with the Windows operating system and not yet with the iOS. The Shariiing Widget is compatible with both (Table 5). So, the main idea is to upload the documents into the same digital environment or share the documents with the environment, display and visualize, manipulate, and annotate (Figure 14). All the interactions will follow the same united logics of the Shariiing collaborative scenario protocol standards.

Figure 13. ENSA Nancy students at the collaborative work session.

Table 5. Shariiing compatibility.

	PC + WINDOWS	MAC + IOS	PRICE
SHARIIING	✓	✗	7500
SHARIIING WIDGET	✓	✓	free

Figure 14. Shariiing work environment basic interactions.

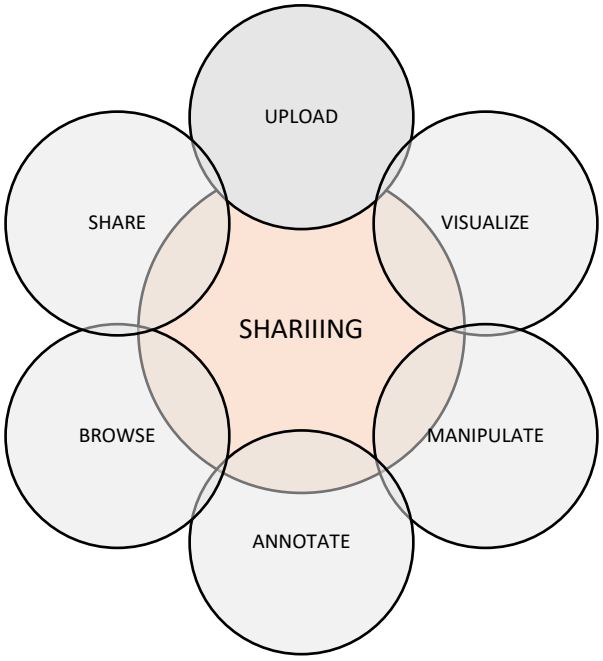


Figure 15. The basic touch screen gestures.

The touch screen can be manipulated directly by hand or with a touch screen stylus (not a capacitive one). The manipulation involves the following basic touch screen gestures: select/deselect, move, scale and rotation (Figure 15) (Immersion company, 2016). Information manipulations in Shariiing have two levels of interaction.

The first is for the general documents manipulations, when the manipulation is due to place the document frame in the digital work environment main frame (Figure 16), and the second one would deliver some possibilities of the interactions with the documents frame and the inside frame interactions possibility.

Shariiing control bar has two main menus – a document choice and control menu, and a button of lock/unlock the control bar position. (Figure 17).

Figure 16. Shariiing work environment with a control bar.

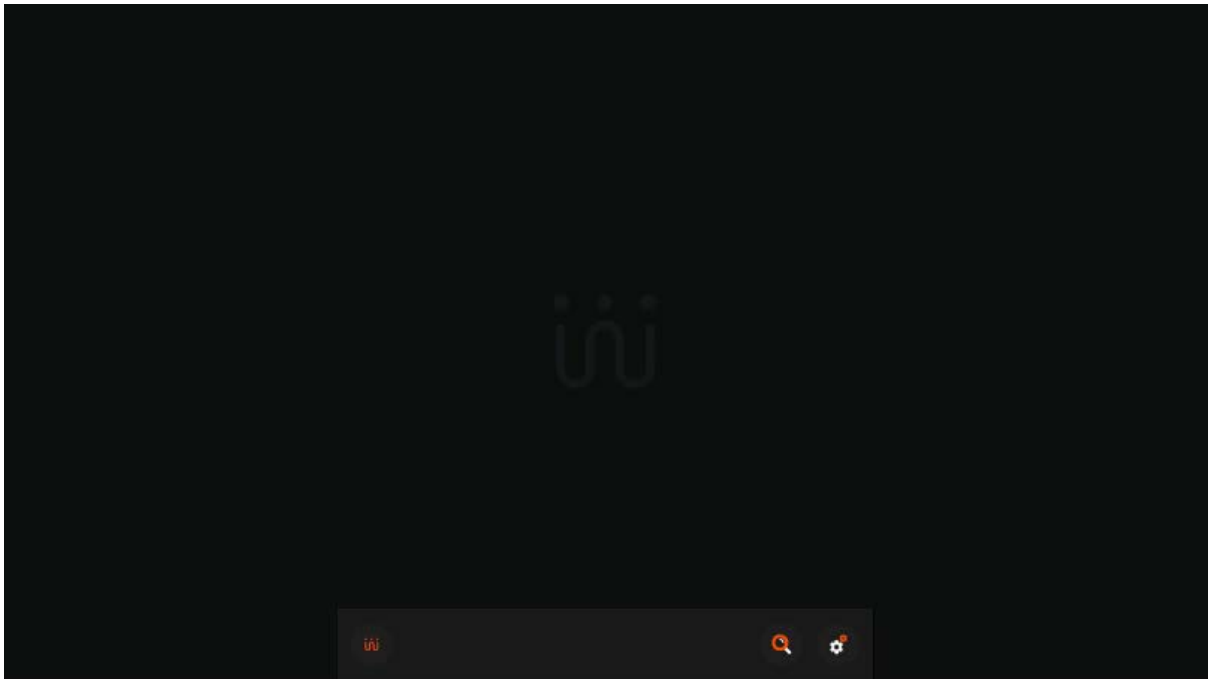


Figure 17. Shariiing control bar basic state.

Figure 18. Shariiing control menu active.

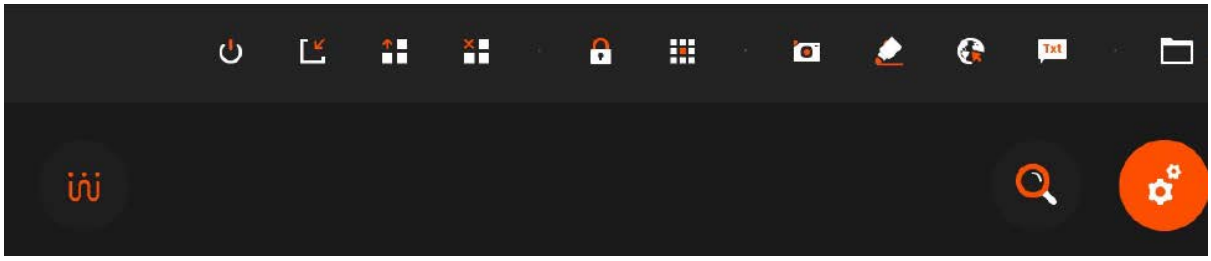
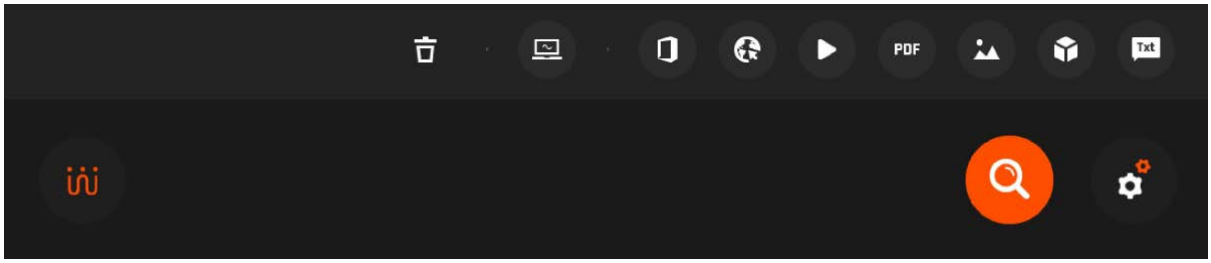


Figure 19. Shariiing document choice menu activated.

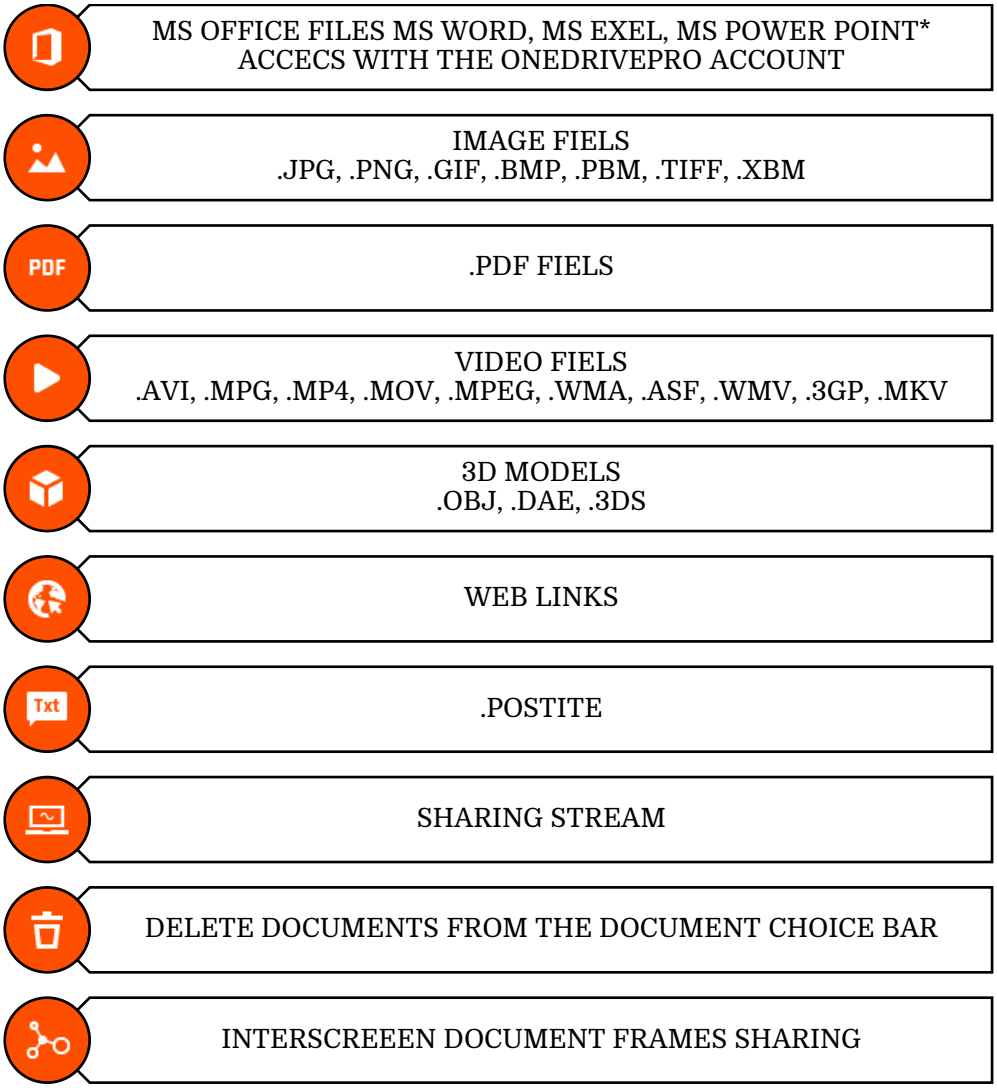


The control menu, activated by a touch of the control menu button, let to: 1. Quit Shariiing, and leads back to Shariiing manager. 2. Minimize Shariiing work environment. 3. Restore frames in a previous position. 4. Close all the opened document frames. 5. Lock of the work environment. 6. Organize the frames of the work environment. 7. Make a print screen picture, available at the image frames menu. 8. Male a work environment annotation picture. 9. Open a web browser. 10. Make a note. 11. Open a file manager.

Figure 20. Shariiing control menu bar options.

Several various file formats are supported for upload to Shariiing: 1. MS OFFICE 365 from the OneDrive Pro. 2. Images. 3. PDF files. 4. Video files. 5. 3D models. 6. WEB links uploaded with Shariiing Widget. 7. Notes. (Figure 21) However, to upload and visualize these files in the Shariiing there are some upload specifications to follow. (Annex II. Shariiing and Shariiing Sender software features and their implementation to the DSCW for the AEC project notes.).

Figure 21. Shariiing supported file formats and the document choice bar functions.



Inside frame manipulations would allow a number of interactions. After choosing the document from the tool bar, the document frame can be: locked (to fix the frame position and to give an access to the inside frame manipulations). Cloned (to have the frame contents and manipulations visible for another users). Fleeting annotation (to make a short-lived annotation during the discussion). Constant annotation (to create a new image within a constant annotation). Options: red color pencil, green color pencil, yellow color pencil, eraser, save, close without saving (Figure 23).

Figure 22. Inside frame manipulations bar.

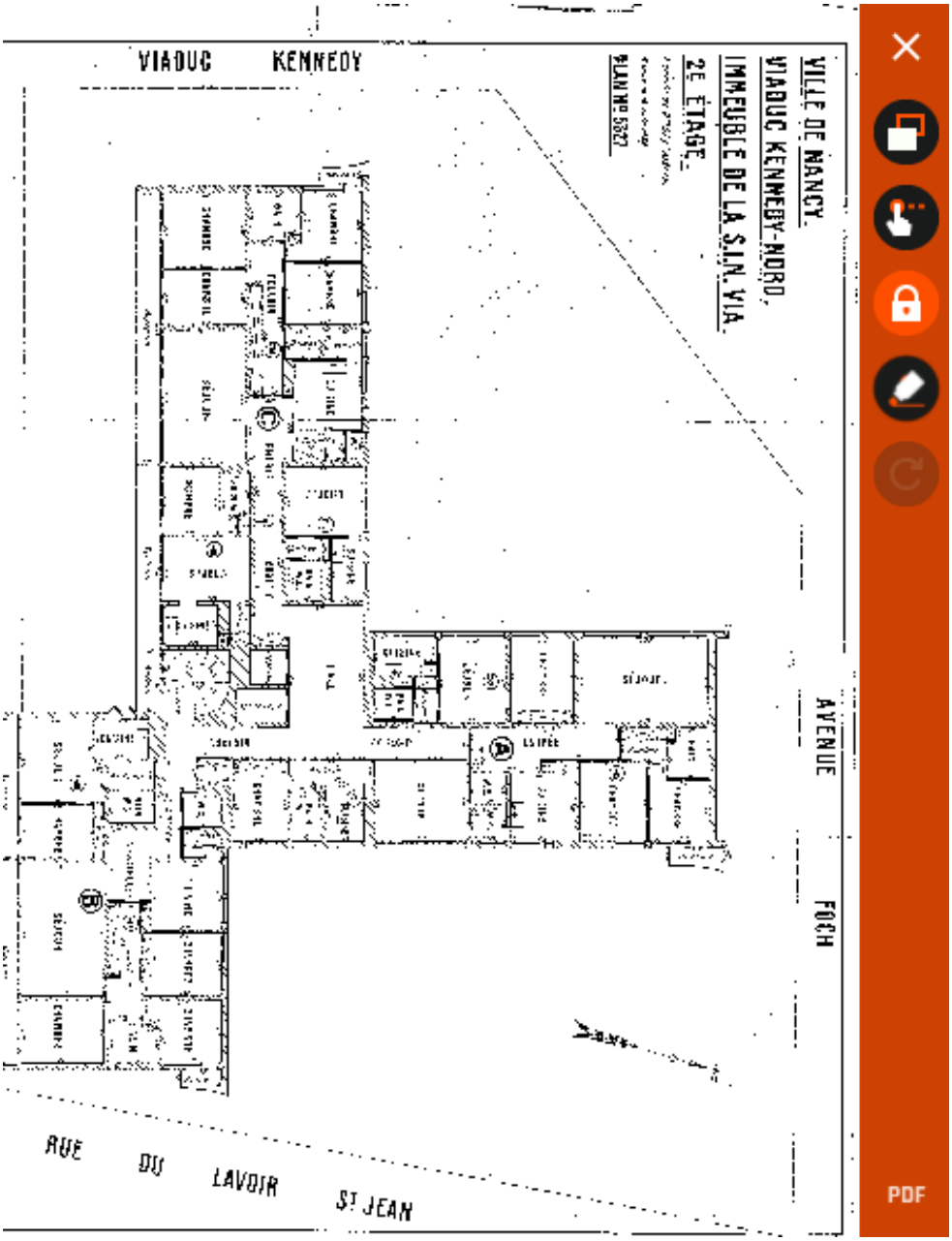
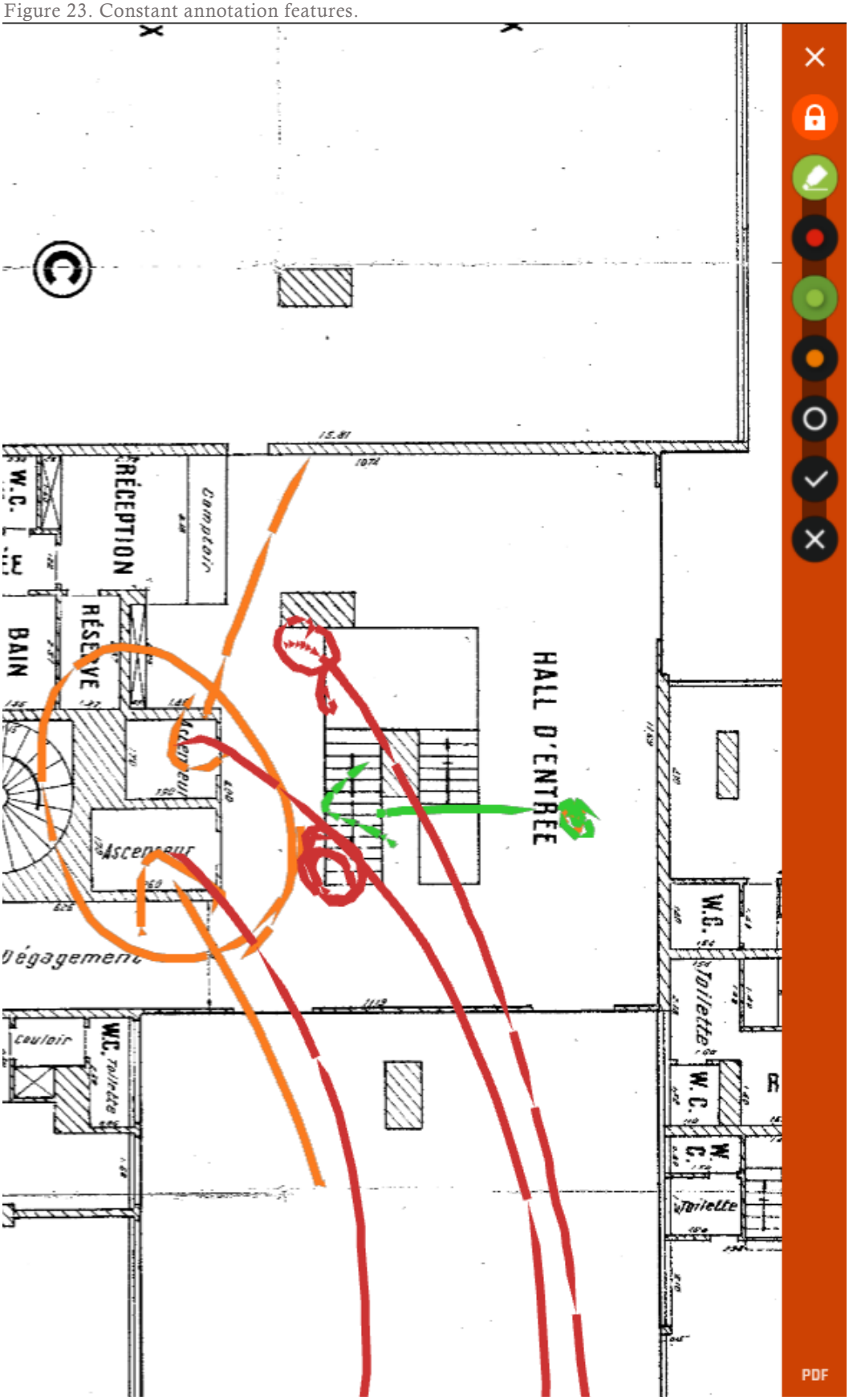


Figure 23. Constant annotation features.



2.4. SHARIIING SENDER (WIDGET) SOFTWARE KEY FEATURES.

Shariiing Sender Widget is a software feature for a connection between the Shariiing session and another computer (connected to the same network). The main utility of such a connection is in a possibility of exchange between a distant computer with the collaboration work environment of the active Shariiing session.

Any computer or a tablet with the Shariiing Widget connects to the active Shariiing session for a number of exchanges. (Figure 25).

Figure 24. Shariiing Widget disconnected (on the left) and connected to the ENSAN2 Shariiing session (on the right).

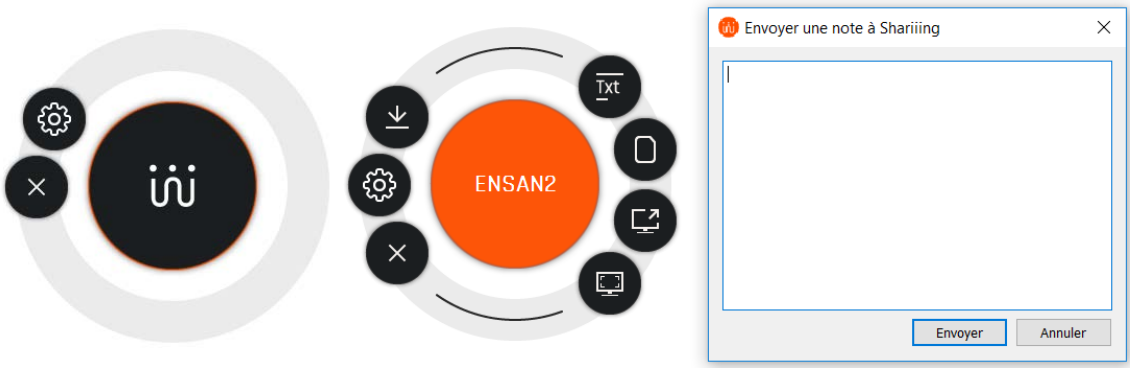


Figure 25. Shariiing Widget options.

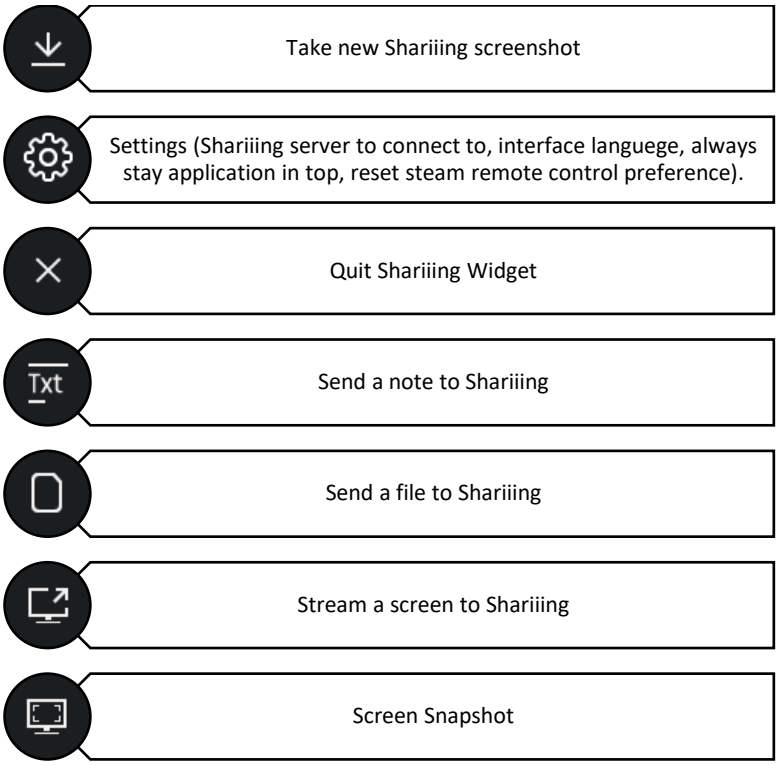
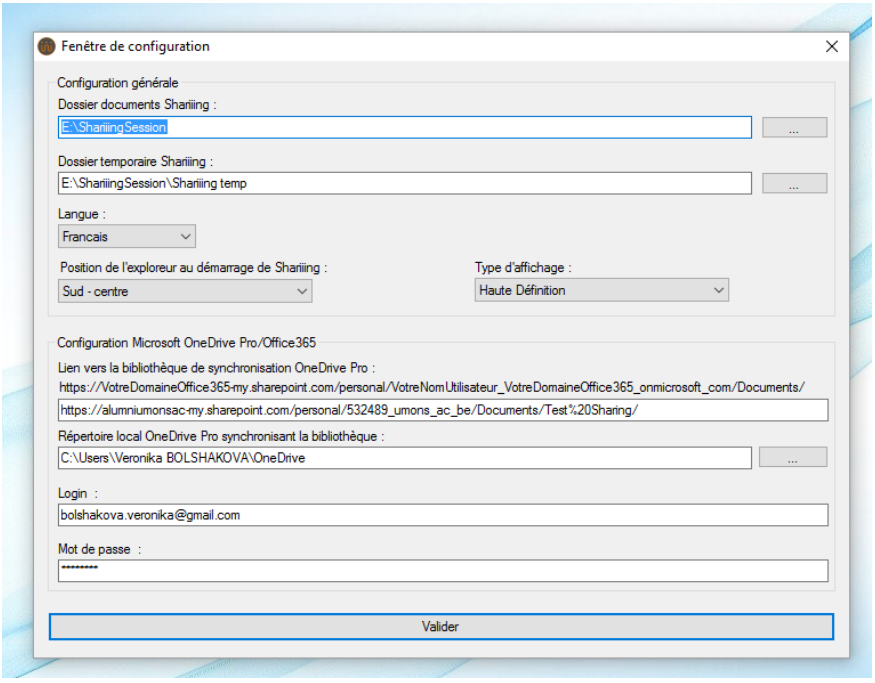
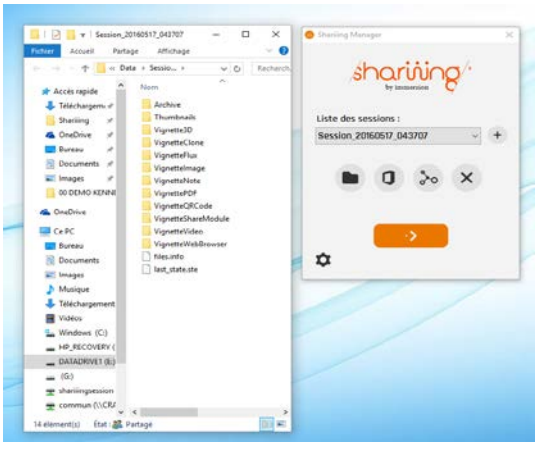


Figure 26. Shariiing Manager and Shariiing session setups.





2.4. DIGITAL COLLABORATION WORKSPACE ERGONOMICS OPTIMIZATION.

The efficient usage of the digital collaboration workspace would be possible with a respect of some certain conditions and suggestions (Figure 27).

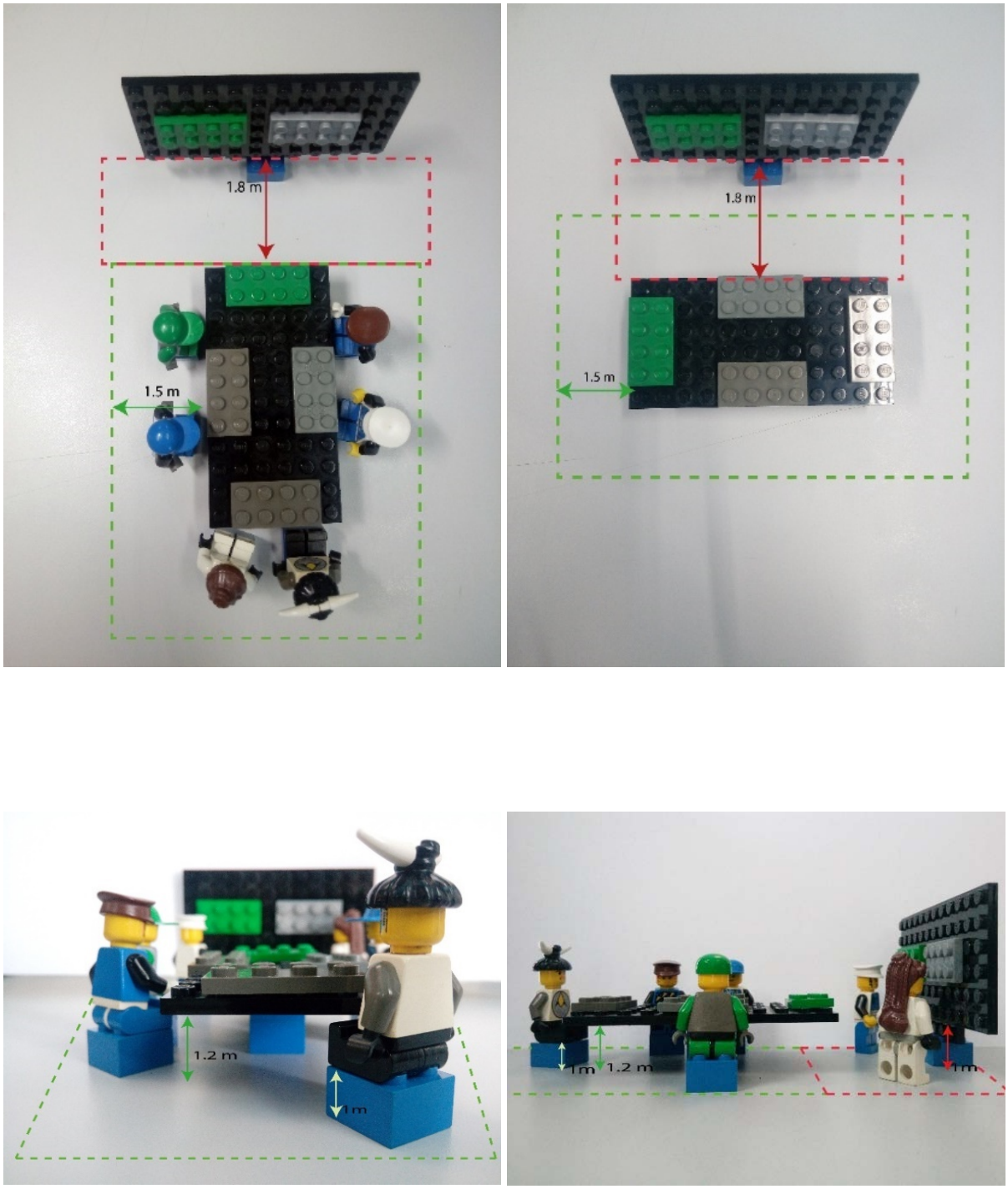
- SPACE SIZE REQUIREMENTS. Some free space must be dedicated to a comfortable and easy moving around the devices. The free space size must correspond proportionally to the size of the digital collaboration devices. In case of the DCW at MAP-CRAI, the free space around the table must have at least 1.5 meters of a distance to the objects. A distance of at least 1.8m between the Wall and the Table would assure a good visibility of the screen and enough free space in front of it. Likewise, for a person with disability the comfortable circulation around the Table and in front of the Wall will require 1.5-1.8 meters.

- EQUIPMENT POSITIONS. The Table and the Wall should be adjusted to a comfortable height from the floor. The Wall display of a size of 98''. The lowest side of the screen should be better placed on the height of 1 meter from the floor, so the user wouldn't need to bend much while using the touchscreen. The horizontal surface of the Table has a is fixed on a height of 1.2 meters to allow an easy access. Six users can take their places around the table, standing or sitting on a high chair during the collaboration session. The wooden part of the Table has a place for a touchscreen tablet or a 15'' laptop, or a notepad around the touchscreen area.

- LIGHTS AND AIR CONDITIONS. Booth screens must be placed in the room in a way to avoid catching any reflexes from the lights sources (lams, devices indicators, windows…) to provide a visual comfort for users. A possibility of aerate well the collaboration workspace room must be provided due to evacuate the heat from the working electric devices (screens and computers), and provide a good quality of air for the users.

- MINIMALISTIC DECORATION of the workspace would assure a concentration of the user's attention during the sessions. But a there must be some place for the personal items of users (bags, coats, notepads, documents, etc.).

Figure 27. Digital collaboration room space arrangements recommendations.



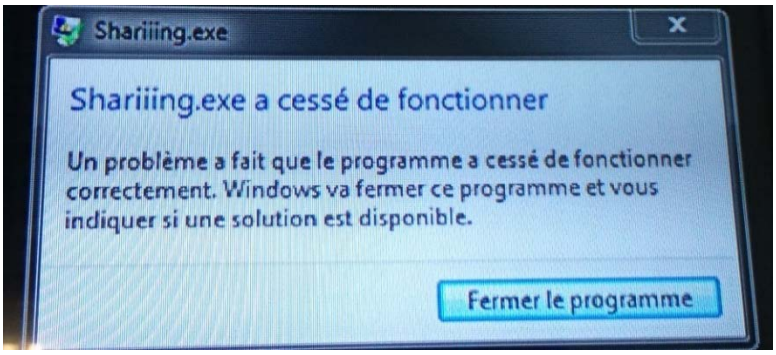
2.5. HARDWARE IMPROVEMENT AND ORGANIZATION POSSIBILITIES.

The system's hardware and management should well support a correct performance of the digital collaboration workspace software might. The current hardware of the Wall and the Table have some relatively high performance abilities with the strong processor, the RAM, and the graphic card. But the Windows 10 doesn't leave much place on the 100 GB SSD, which is supporting the operation system and the collaborative software. So, such hardware configuration can't fulfill a proper software support and often leads to an error of the "Shariiing.exe a cessé de fonctioner" (Figure 28). An additional space on the SSD would solve the problem.

Two wireless keyboards with an integrated touchpad assure a control to the computers so to give an area of access instead of a fixed spot and a circulation facility around the table and in front the Wall without cables.

A collaboration session software manipulations are assured with a keyboard, touch pad and a touchscreen, but there is a possibility to integrate a graphic tablet as one of the manipulators as well. Users manipulate a verity of the document types during the session, leap motion manipulator might be as well integrated to manipulate the 3D models.

Figure 28. Hardware related error of Shariiing.



CHAPTER CONCLUSIONS.

The current DSCW is on a rather testing-and improvement research stage, experimental devices for a research but not necessary autonomous wide use by the AEC professionals or other collaborators. The equipment setups process protocols are not perfect end often require an inventive solution. However, the DSCW is ready to use and reception the experiments and work sessions.

3. DIGITAL SYNCHRONOUS COLLABORATION SCENARIOS.

3.1. SCENARIO TYPES.

A scenario should clearly define the collaboration session protocol. It will include the essentials of the organization proses to simplify the collaboration sessions managements and of course define the course of the collaborative session procedure.

Scenarios might be classified by a number of sessions, punctual unique session or a long-term project development set of sessions. The intention of the session introduces the first session aim. The Introduction – is rather an educational type of session, Practice is used by the collaborators for the project development purposes. (Table 6).

A scenario defines a session type as well, which will set a main session task. (Table 6). Every session type has its own function, requires a specific equipment set, and offers a certain number of roles to the collaboration session (CS) users. (Table 7)

Table 6. Scenario types.

Period	Unique			Unique / set				
Intention	Introduction			Practice				
Type	Demonstration	Appropriation		Briefing	Value engineering		Creative development	
		User	Manager		Project	Organization	Project	Organization

Table 7. Scenarios kits.

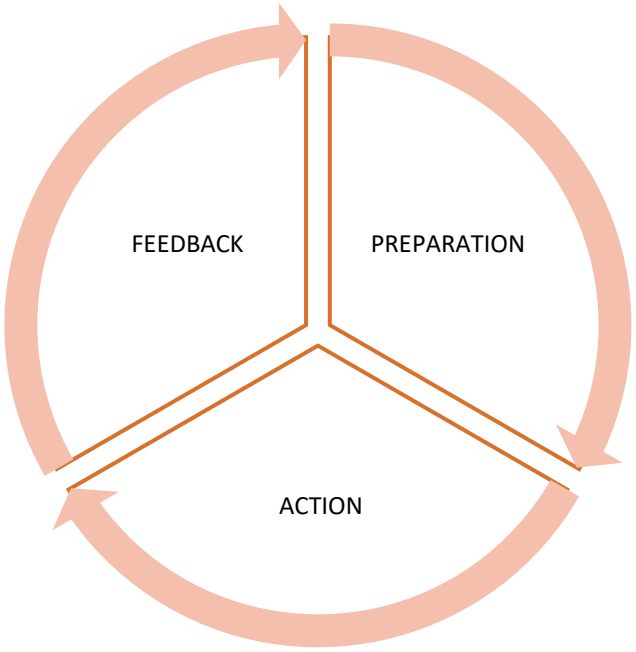
SCENARIO TYPE		FUNCTION	DIGITAL SURFACES			PARTICIPANT ROLES				
			Wall	Table	Tablet	Manager	User	Audience	Tech	Reporter
Demonstration		General overview	✓	✓	✓ *	1/N	0	N	1	1/N
Appropriation	User	User training	✓	✓	✓ *	1	1-4	0	1	1/N
	Manager	Manager training	✓	✓	✓ *	1	1-4	0	1	1/N
Briefing		Information distribution	✓	✓ *	✓ *	1/N	0	N	1	1/N
Value engineering	Project	Decision making	✓	✓	✓ *	1/N	1-6	N	1	1/N
	Organization		✓	✓	✓ *	1/N	1-6	N	1	1/N
Creative development	Project		✓	✓	✓ *	1/N	1-6	N	1	1/N
	Organization		✓	✓	✓ *	1/N	1-6	N	1	1/N

3.2. COLLABORATIVE SESSION PROCEDURE AND A PROJECT DEVELOPMENT PHASE.

Every work session setup passes through the stages of the session cycle, which are defined by the basic purposes. There is no CS without a preparation stage. And after the CS there is always a feedback reporting to fix the new tasks and be sure what to prepare for the next session. Every element of the cycle completes the collaboration session full cycle.

Every session action passes through the following stages of protocol. (Figure 30. Meeting procedure.). An informal introduction opens the session and give some time to settle, the commitments progress brings all the user directly to the current stage of development and to the actual work context. An announcement of the meeting plan gives a clear order to the session and sets an attention concentration on the important tasks. Discussion, evaluation, and decision are the typical work phases of the session. The new commitments close the session, and with a feedback every interactor is sure about the further steps to take, usually the feedback materials become a basis for the next session preparation.

Figure 29. Session cycle.



For the development of the architecture project in France the government has developed a protocol of the project development phases. (Table 8). This phases give a project development directive, and untie all the project development documentation under the same classification, however, some tasks or interactions sometimes can be repeated not on their proper development order.

Such a system gives to all the AEC professionals a schedule of their interactions and check points of the information diffusion, and predefines a collaboration sessions roles-participants and the contents. This is a very specific organization of the collaboration typical and unique for the AEC industry, where everything depends on the project (the scale, the phase of t=development, specifics, etc.)

The current progress of the project development methods towards the BIM methods gives a new scale to the project development inter professional interactions. (Figure 30). Such a change gives an additional complexity to the existing order of interaction per the project development phase.

The specific domain professional can participate in a collaborative session not necessary when hi part of the work is in a development, but also make some other different interaction types to assure the project development quality. (Table 9).

Figure 30. Meeting procedure.

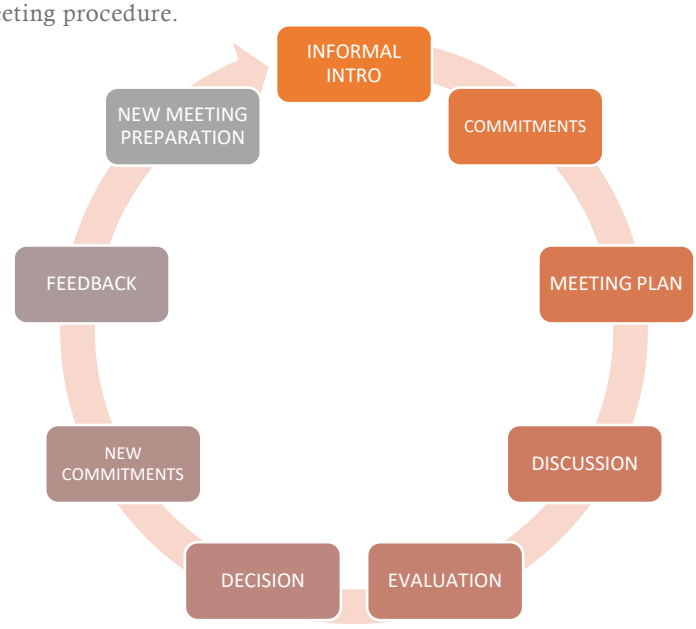


Table 8. Construction project development phases in France.(*Décret n°93-1268 du 29 novembre 1993 relatif aux missions de maîtrise d'oeuvre confiées par des maîtres d'ouvrage publics à des prestataires de droit privé*, 1993).

1. PROJECT FEASIBILITY	Architect meeting	Esquisse study (ESQ)	Pre-project study (AVP)	Pre-project overview (APS)	Pre-project definitiv (APD)	Building permit application (DPC)
2. DETAILED CONCEPTION	Project study (PRO)					
3. PROJECT PLANNING	Study and execution plans (EXE)	Construction file (DCE)	Construction plans			
4. TENDERING	Works agreement survey (ACT)					
5.CONSTRUCTIOIN	Project realisation managment (DET)	Construction managment	Construction and schedule supervision (OPC)			
6. DELIVERY OF THE BUILDING	Project delivery consulting (AOR)					

Figure 31. Project team communication using construction collaboration technologies.(Wilkinson, 2005)

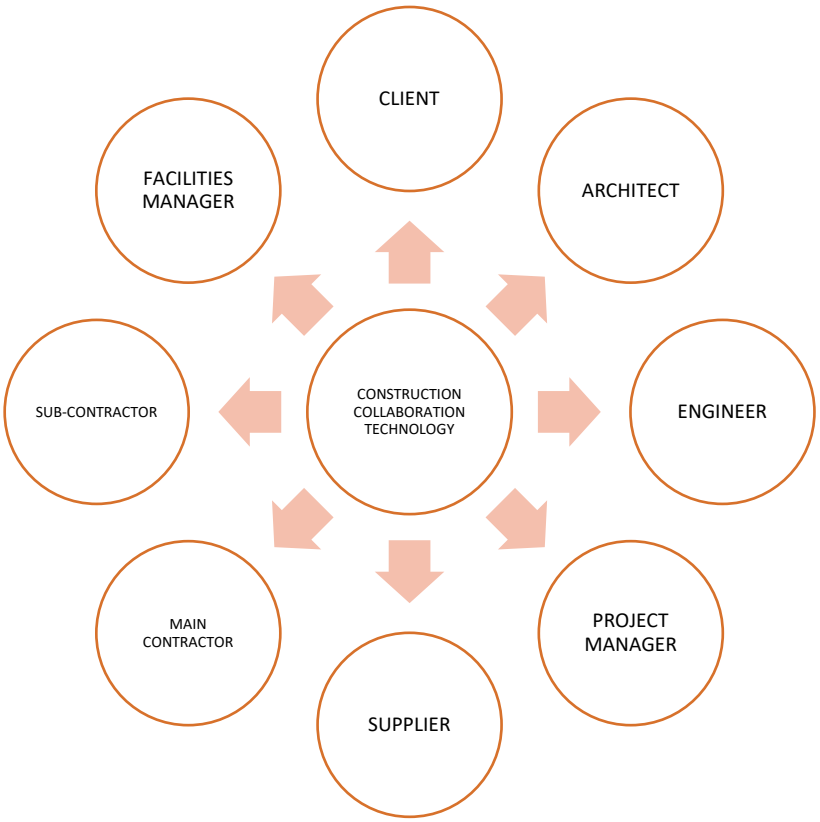


Table 9. Action types for the project team roles.(Huges and Murdoch, 2001, p. 25)*modifiend

ACTION TYPES		
OPERATING	**CONTROL**	**MANAGEMENT**
Operating Carrying out work (i.e. performing an operation) on some aspect of the project, and having overall responsibility for its output.	Monitoring Recording and filtering information about an operation and communicating it to those who may act.	Coordinating Ensuring that information flows successfully between organizational links and assembling diverse outputs.
Cooperating Carrying out work as part of a team or committee with partial responsibility for output.	Supervising Comparing progress with a predetermined plan and bringing about some sort of response to the situation.	Directing The executive responsibility for ensuring that the output of activities is orientated towards the objectives of the project.
Advising The provision of technical or other information when asked for it. Typically undertaken in the construction industry by professional consultants.	Resourcing Ensuring that those who carry out operations have sufficient resources (in terms of both skill and economic resources).	Recommending Passing information or the results of an activity to someone who must take a decision on it.
Receiving Receipt of information about the project for purposes outside the management of the project: for example, the accounts department of a client organization.		Approving The executive function of taking decisions about the output of activities. This decision will usually form the input of a subsequent activity.

3.3. PROJECT DEVELOPMENT PHASES CONTENTS AND A SESSION PREPARATION PROTOCOL.

A clear understanding and expressions are the success key of the efficiency of collaboration for the different branches and domains. When the task and the problem are well visualized, the team spends a time on a problem solving and not on a problem description, understanding and then a solution research.

The Table 7 visualizes a project development process in a clear way, easy to understand for a non-AEC professional and even for the professional of the domain. This one is the client understanding of the process orientated, and yet it contains all the main specific professional's interventions. Such representation of the project would give a clearer view to the project development actors than the construction development phases France protocol.

Any of the project development stages would require an information exchanges and collaboration between the project development. The following diagram proposes a session preparation protocol, which would give a clear session contents and aims visualization even before the meeting, and encourage the exchanges between the collaborators.

The preparation has a phase of the aim definition, contest gathering, contents confirmation and session set-ready confirmation. And requires a respect of the roles and functions of between the collaborators. (Figure 32).

Table 10. Design phases.(Hine, 2012)

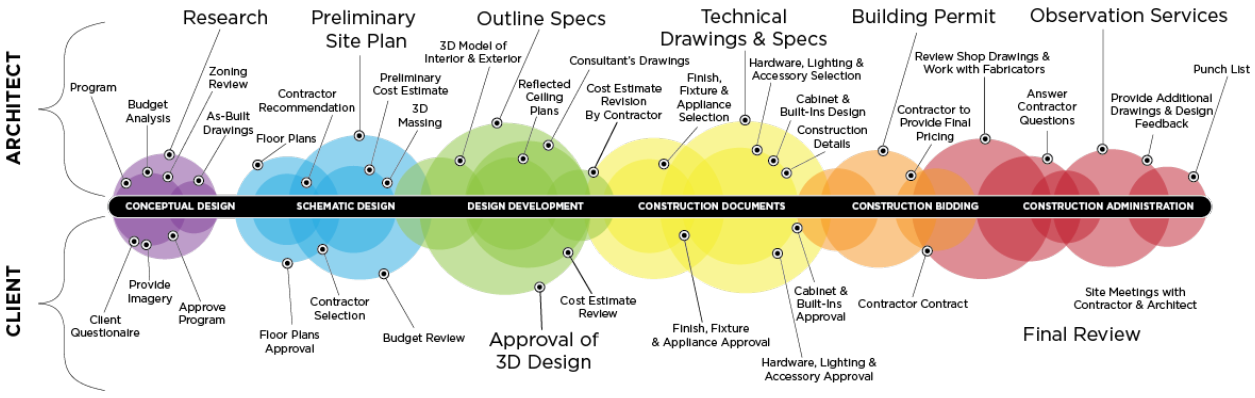
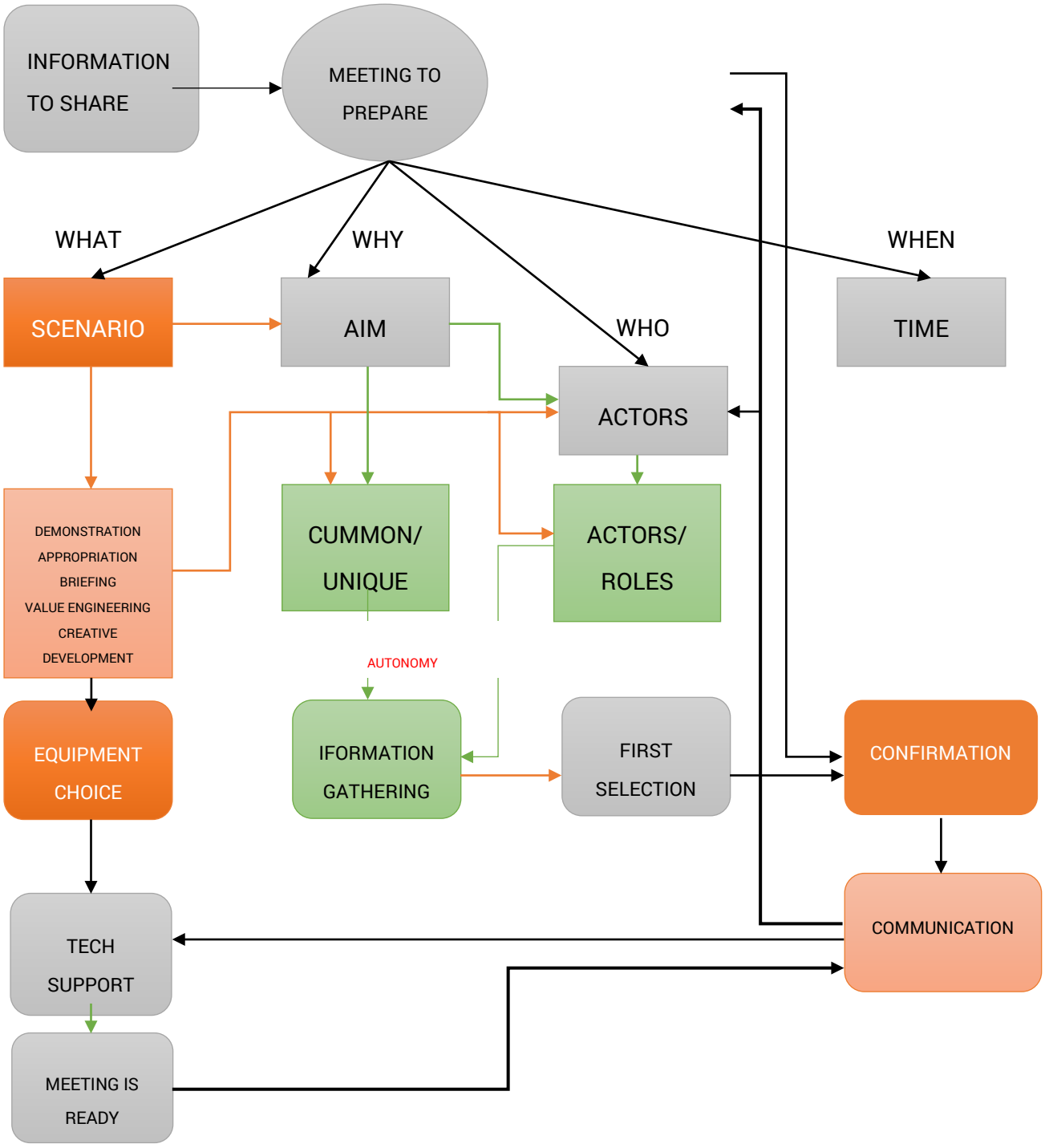


Figure 32. CS preparation algorithm



4. DIGITAL SYNCHRONOUS COLLABORATION EXPERIMENTS.

4.1. NEW TECHNOLOGIES AS A CATALYZER OF THE EXISTING PROCESSING METHODS RECONSIDERATION.

The main aim of the Digital synchronous collaboration experiments at the DCW of MAP-CRAI is to develop and test several hypotheses about a possible usage, as well as an existing and possible future usability of the DSCW with Shariiing in general, and the application for the AEC industry professionals, and in addition to search for some education and research applications of the digital collaboration methods (Seung-hee Lee, Richard Magjuka, Xiaojing Liu, Curt J. Bonk, 2006).

A few questions set the problematic of the research:

- What would be a main advantage and added value of the digital synchronous collaboration compared to the non-digital one?
- And do the users benefit in efficiency on a decision making or creativity with the present digital collaborative tools and features?
- How does the DSC change or influence the existing collaborative methods?
- How this technological solution can adapt to existing requests of the AEC industry, and what should be established in the future?
- And besides the user's opinions about the collaborative experiences has a value and gives a lot of information for the further improvements.

Therefore, the result of the experiment would remain a potential basis for the further development and AEC adaptation of the collaborative tools and features, and, of course, simultaneously with the reconsideration of the collaborative methods and habits.

The participants of the experiment were proposed to fill up a questionnaire with some questions concerning their experience and DSCW opinion.

Apart the experiment results, many feedback discussions, based on the impressions from the equipment demonstration-appropriation sessions, have completed some observations and opinions for the further methodology and technology improvement.

4.2. STUDY PROGRESS AND EXPERIMENT PREPARATIONS.

The first two stages have allowed to reveal several technical problems and difficulties with the DSCW equipment setups and with the information types to collaborate with. Besides some technical problems, some observations about the digital collaboration protocols specifics and needs.

The Equipment Study, first was dedicated to the exploration of the DSCW Wall and Table devices, and has revealed several the technical arrangements and the software limits. For example, such as an optimal screen's position, or the computer systems updates and adjustments, or some equipment changes. (as a new wireless keyboard and touch screen styluses addition to the system). Shariiing software setups have included a numerous séances of the software developers distant technical support by Immersion, software reconfiguration, and some Shariiing file formats compatibility research. For example, a correct way to export the 3D models from the architecture software native formats to the Shariiing compatible 3D model file format (Figure 21) without any data loss.

Table 11. progress of the study and the experimentations.

	Research progress stage	Main tasks
1	Equipment study	Equipment setups, adjustments, usages, and limits
2	Pre-experimentation	Demonstration and appropriation sessions without a strict scenario protocol, first decision making session
3	Scenario adjustments	Correlation of the experiment scenarios, agenda coordination, experiment materials selection
4	Experiments run	Experiment proceeding and feedback collecting
5	Results analysis	Analysis and conclusions

The Pre-experimentation has permitted to test and develop the Demonstration session scenario, important opinions, essential usages, advantages to show, and the digital collaboration workspace current configuration limits. All the collected information led to the correlations of the hypostases of the collaboration scenarios.

After the scenario adjustments, the experiments run became possible. The experiments were presenting DSCW Demonstration session scenario experiment, DSCW Appropriation session scenario experiment, DSCW Creative development and decision making session experiment, also some of experiments were not pre-set at the DSCW, but were testing a decision-making session for an ongoing project of an architecture agency.

4.3. DSCW DEMONSTRATION SESSION EXPERIMENTS.

This experiment aim was to communicate the existing abilities and possibilities of the digital synchronous collaboration workspace in a case of collaboration on an architecture project, with some demonstration of the possible uses of the DSCW, its advantages and limits, as well as the digital collaboration method ones.

This type of scenario requires a speaker – Collaboration manager, who does the presentation and oversees all the manipulations and interactions. The Audience takes an observation role.

The demonstration scenario was applied several times and assured an introduction to such a technology and methods to the AEC professionals public (Architects, engineers, developers, architecture and structures professors, AEC researches, architecture students, city administration, large public at the ENSAN open doors day, etc.). The main task was to introduce the DSCW concept and make a brief overview using the architecture project documents as a content for the Shariiing session. This type of information gives a clear and realistic scale of the possible interactions, easy to understand by the AEC professionals.

All sessions had the same number of documents within an information about a study project and some additional media related to the architecture and collaboration. (Table 12). The presentation follows a pre-developed protocol to assure a clear understanding and a full cover of details.

Figure 33. ENSAN students on a demonstration session at DCW of MAP-CRAI.

Table 12. DSCW presentation demonstration experiment resume.

SESSION	DSCW PRESENTATION. AEC INDUSTRY IMPLICATION CASE.	NOTES
PROJECT TYPE	Mixed: residential/public	o The conceptual project has some essential characteristics of any architecture project but contains no technical details, this offers a good visibility for the tools. o The demonstration manager is the only role to be prepared in advance. o All the DSCW equipment should take a part in the demonstration. o All supported document formats and information types should assure a full image of the software capacities.
PHASE	ESQ/AVP	
EXPERIMENT AIM	1. to show the of the existing software and devices abilities 2. to show possible uses for the digital synchronous collaboration sessions, 3. to show the new collaborative method advantages and limits, 4. to show potential development ways.	
ROLES OF THE ACTIVE USERS	• Collaboration manager • Audience	
KIT	• Wall + Shariiing • Table + Shariiing • Laptop + Shariiing sender	
DOCUMENTS PREPARED FOR THE CS	• 3d model (obj) • Perspectives (jpg) • Master plan (jpg) • Cut-section (jpg) • 3D cut-section (jpg) • Structure axonometric perspective (jpg) • Project presentation notice (pdf) • Web-links • Notes • Demo videos	
SESSION PROCEEDING	1. Welcome, Informal part, greetings, settling. (Collaboration manager > Audience) 2. Session aim and contents presentation. 3. Devises presentation. 4. Software presentation. 5. Collaboration session setups. 6. Shariiing Manager options and usages 7. Shariiing work environment and a control bar. 8. Control bar control menu, environment manipulations, documents upload to the session. 9. Control bar document choice and types. 10. Basic manipulations, inside frame manipulations. 11. Documents display and annotation. 12. Information share flows. 13. Shariiing Sender features.	o The prepared protocol must be followed due to assure the full cover of the demonstration tasks and respect the time limits of the demo session. o The main accent should be made on the visualization, annotations, and collaboration during the presentation
	14. Resume, further development tasks. (Collaboration Manager > Audience)	o CS final point closes the session

FEEDBACK	15. CS critics and opinions. (Audience > Collaboration Manager)
OBSERVATIONS	The profession and an experience in the domain make no difference for understanding the DSCW presentation, however, rather audience members with a well gained experience in the domain AEC tend to ask some very specific questions (costs, efficiency, reports, types of documents, upload techniques, educational possibilities, etc.), and the young professionals have more questions about the interface manipulations and interactions. The most asked question is about the possibilities of annotations and 3D models manipulation. Also, common question is about a session report information creation.
CONCLUSIONS	1. Such a brief demonstration of the possibilities of DSCW introduces the potential users to the method and gives an opportunity to imagine their own scenarios of collaboration with the DSCW. 2. The audience understands quickly the main princes of the DSCW, which gives some confidence to the new technology and further tests and implementation facilities. 3. Even after a short introduction the potential users are capable foresee the current problems of the DSCW interface and features which will require an adaptation and development in the future.

4.4. DSCW AND EDUCATIONAL USE - DECISION MAKING SESSION EXPERIMENT.

DSCW as an instrument at the ENSAN final architecture projects development session experiment. Another part of the pre-experimentation phase of the study was a session of the DEA graduate project development-advancement session, with the students of the 5th year and their project survey professors.

The resume and observations about the CS are assembled in the Table 13.

Figure 34. ENSAN final project work session with professors and students.

Table 13. DSCW student architecture project experiment resume.

SESSION	DIGITAL SYNCHRONOUS COLLABORATION SESSION FOR A PRESENTATION, CREATIVE DEVELOPMENT AND DISSECTION MAKING AROUND THE FINAL STUDENT ARCHITECTURE PROJECT.	NOTES
PROJECT TYPE	Mixed: residential/public (Students project)	o Student project accentuates the essentials of the development process without technical details, which gives a certain degree of imagination liberty. o Every professor has developed the educational methods per his vision of the school, so the session was adapted to the particular method of the participants o The presented content corresponded exactly to the requirements of the standard CS, including the 3D model
PHASE	ESQ	
EXPERIMENT AIM	1. To present a new method of the project display and collaboration to the professors 2. to test some possible uses for the digital synchronous collaboration sessions, 3. to engage all the users into the decision-making session, 4. to make decisions about the father projects development, 5. to test and reveal the digital collaborative method advantages and limits, 6. to find some potential development ways.	
ROLES OF THE ACTIVE USERS	• 2 Architects / Architecture professors • 3 Students	
KIT	• Wall + Shariiing • Table + Shariiing • Laptop + Shariiing sender	
DOCUMENTS PREPARED FOR THE CS	• 3d model (obj) • Perspectives (jpg) • Master plan (jpg) • Cut-section (jpg) • 3D cut-section (jpg) • Structure axonometric perspective (jpg)	
SESSION PROCEEDING	1. Welcome, Informal part, greetings, settling. (Collaboration manager > Actors) 2. Session aim and contents presentation. 3. Devises presentation, Software presentation. (Students >Professors) 4. Shariiing work environment. Control bar control menu, environment manipulations, Control bar document choice and types. (Students >Professors) 5. Basic manipulations, inside frame manipulations. (Students >Professors) 6. Documents display and annotation tools. (Students >Professors) 7. Project presentation. (Students >Professors) Master plan presentation Project 3d model display next to the GF plan display. 8. Collaborative creative development. (Professors > Students) Plan and 3D model manipulations (without annotations).	o The main accent was made on the visualization, annotations, and collaboration possibilities to introduce the DSCW to the professors and inspire an implementation in their practices. o However, the session didn't involve any additional interactions compare to a standard CS o First part – presentation,

	9. Resume, further development tasks. (Professors > Students)	second part – critics and opinions about the project o CS final point closes the session o The method was not fully integrated to the CS
FEEDBACK	10. CS critics and opinions. (Audience > Collaboration Manager)	
PRODUCED DOCUMENTS	No documents have been produced during the session.	
OBSERVATIONS	1. The project presentation part of the discussion did allow to present better the project due to the high quality of the images well represented on a 4K screen, possibility of having several documents in the same time and to change their representation scale. (Usual projection causes some loos of the details quality.) 2. One part of the collaboration group (the students) was very natural and entailed with the digital collaboration workspaces, and had no issue using the Shariiing. But another part (professors) took rather an observatory role rather than an active user of the digital collaboration workspace, which create a misbalance of expression forms. 3. In this case the project development depends completely on the project development methods of the Atelier of the Architecture project led by professor's vision of the architecture. So, they have notice that per their vision of the development of the architecture project: "The Conception proses has nothing in common with the project's presentation." So, to discuss the project in some conditions of the limited time became more important than to discover and apply the digital collaboration method. 4. The final decisions and suggestions were made only in a verbal way with the project documents only displayed on the touch-screens but without annotations or other manipulations.	
CONCLUSIONS	1. DCW improves the project information presentation (especially for the images and 3D models). 2. Digital synchronous collaboration method efficiency in a case of the decision-making objectives of the collaboration would depend on a basis of the initial methodology of the work. 3. The psychological comfort at the digital synchronous collaboration session wouldn't be possible without users having trust in their own abilities of mastering the collaborative methods and equipment. 4. Coordination and proper session preparation are influencing directly the quality and efficiency of the collaboration session. 5. An integration problem for any new technology, often trying and appreciation the innovation is the first step but to make the second step towards its application will be required an effort of the habit change and some mind and method flexibility.	

4.5. DSCW APPROPRIATION SESSION EXPERIMENT.

The DSCW Appropriation session experiment is an important experience to learn more about the user – equipment interactions. This experiment main aim was to educate the future users of the DSCW to work with the equipment, being able to create a new session, upload the documents and fell a confidence in a use of the equipment and DSCW method application. As well, as evaluate the efficiency in use, advantages, and limits of the DSCW devices for the AEC industry implementation.

This type of scenario involves the users into an active interaction with the DSCW interface and helps to use the received training skills immediately to be able to accomplish some simple typical collaboration tasks.

The scenario was applied at least eight times for an DSCW session experiment. All the users had to create a new session and fill it with the contents of the project (Kennedy tower residence as a project simple). Thus, the session is completely new and the very first challenge for the user is to prepare and upload the contents. Then the training manager proposes to study the Shariiing interface buttons and simple content manipulations. Usually at this stage the user starts to gain a self-confidence and discovers-tests the Shariiing features with the minimal guidance. Users have no difficulties understanding the interface and documents manipulations, but should train several times before understanding the frame clone, frame send from screen to screen and the frame sharing on the both screens options.

A very important part of the training is to give a simple manipulation tasks by the user to another user, this implies better the understanding of the DSCW abilities and shows some potential further usages. All the training sessions had the same number of documents within an information about the project. (Table 14). The same documents were used for the decision making – creative development sessions experiments, so the users would not spend time on a documents study but will already know which type of the document is available, how to manipulate it and which information it gives. The continuum between the training and a decision-making session is very important and gives a possibility to apply the received training and learn to use it for the task solving.

Figure 35. DSCW appropriation session for a PhD student at MAP-CRAI.

Table 14. DSCW appropriation experience resume.

SESSION	DSCW APPROPRIATION EXPERIENCE	NOTES
PROJECT TYPE	Residential	o Well-developed basic material of this project offers a good visibility and manipulation field for the DSCW tools. o User prepares the session with all the accessible tools of the DSCW o A few documents should be uploaded to the session to assure the full DSCW management education for the user o In addition to the documents a sharing flow tools make an important and rather complicated part of the Shariiing interface.
PHASE	ESQ	
EXPERIMENT AIM	4. to educate future users for the DSCW sessions. 5. to test and reveal the digital collaborative method advantages and limits. 6. to find some potential development ways.	
ROLES OF THE ACTIVE USERS	• Collaboration manager • Actors	
KIT	• Wall + Shariiing • Table + Shariiing • Laptop + Shariiing sender	
DOCUMENTS PREPARED FOR THE CS	• 3d model (obj) • Perspectives (jpg) • Master plan (jpg) • Cut-section (jpg) • 3D cut-section (jpg) • Structure axonometric perspective (jpg) • Videos	

	• Web pages • Text notes • Sharing flow	
SESSION PROCEEDING	1. Welcome, Informal part, greetings, settling. (Collaboration manager > Audience) 2. Session aim and contents presentation. 3. Collaboration session setups. 4. Shariiing Manager options and usages. 5. Shariiing work environment and a control bar. 6. Control bar control menu, environment manipulations, documents upload to the session. 7. Control bar document choice and types. 8. Basic manipulations 9. Inside frame manipulations, frame by frame. 10. Documents display and annotation. 11. Information share flows. 12. Shariiing Sender features. 13. Manipulations ask achievements by the users. 14. Session report share.	o The main accent was made on the visualization, annotations, and collaboration possibilities of the DSCW, the users has to understand the interface and learn to use it for the CS tasks. o First part of the session usually builds a certain level of the user confidence in the tool o After a few manipulations, all the users are trying the interface capacities guided by the intuition o A simple appropriation session must be followed by a tasked decision-creative development session to assure a full confidence of the user in his own capacities of an autonomous usage of the DSCW.
FEEDBACK	CS critics and opinions. (Audience > Collaboration Manager)	
PRODUCED DOCUMENTS	Sketches, annotations, text notes, print screens.	
OBSERVATIONS	1. Users understand well and immediately the general manipulation gestures (move, scale, rotate) but they must repeat at least three times the inside frame manipulation tasks to get used to the inside frame manipulation gesture specifics of use (frame locker, clone, annotations, zooming and movements inside the frame, etc.). 2. Users understand quickly the concept of Sharing screens and sessions. 3. Users understand as well, a difference between clone and a shared document, 4. Users interact with the both touch surfaces. 5. All annotative gestures preferred to be made with a help of a stylus. 6. Very difficult appropriation of the 3D model manipulations. 7. AEC professionals feel more confident in their abilities of the independent use of the DSCW after the appropriation session than their younger colleges. In general, before the beginning of the appropriation session the users of the 18-25 age group have more confidence than their elder colleagues in a capacity to be efficient with technologies, but in the end of the session the first category of users didn't have an impression of being capable to use in autonomy the DSCW, from another side, the second category of user felt confident and ready to try the implication of the DSCW.	
CONCLUSIONS	In general, all the users have achieved an aim of beefing an independent user of the DSCW, as well as, a user's point of view critics of the existing configuration of the DSCW. Also, in general, all user categories seem to have same level of competences after the training. Such abilities confidence leads to a creativity for the problems solution, different users prefer to operate the information in their own way to respond to the same kind of task, which shows a certain flexibility of the DSCW method.	

4.6. DSCW DECISION MAKING SESSION EXPERIMENTS – KENNEDY TOWER PROJECT.

This experiment aim was to evaluate the efficiency of the DSCW devices and digital synchronous collaboration in a case of a decision-making scenario of collaboration on an architecture project, with some decision making and creative tasks.

This type of scenario involves the users into a decision making collaborative process and obliges them to take role in a process, find a way to accomplish the task. The scenario was applied six times for an DSCW session experiment. (01,02,03,04,05,06).

The first task was to invent a concept of the facades renovation, which would also serve as a sound barrier due to the building position in a proximity of the train station. (Facades photos and the 3D model, plans and drawings were representing the existing situation at the Shariiing session). The second task was to invent a concept of the elevators hall renovation, taking in count some technical requirements related to the elevator work. (Hall photos, the 3D model and plans were representing the existing situation at the Shariiing session).

Figure 36. ENSAN students DSCW appropriation-decision making experiment session.

All sessions had the same number of documents within an information about the project. (Table 15). The documents give enough information to the users for their task solving. Booth tasks were proposing a creative problem and a need of a decision to be made, one for the exterior, and another for the interior of the building.

Different professionals have different approaches to the task solving and use the different methods of the information treatment, annotation, and creation, working with the different documents, and proceeding according to their own habits and project development methods.

Some prefer to use only a static picture to create the concept sketch, others build a discussion around the 3D model manipulation, and the scale plan role is one of the most important and efficient type of the information representation for the AEC industry professionals. (Table 16). The session observations and a content resume is assembled in the Table 17.

The collaboration session content assures an enough amount of the project information to fulfill the tasks, and represents also a possible variety of the project information sources typically required for the project discussion. (Table 15.).

Table 15. DSCW decision making session experiment basic contents.

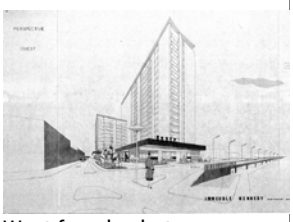
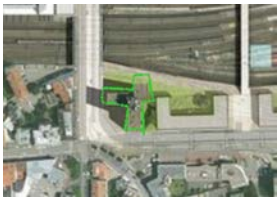
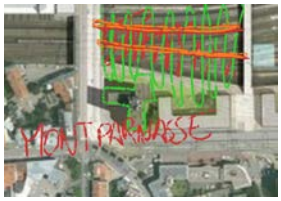
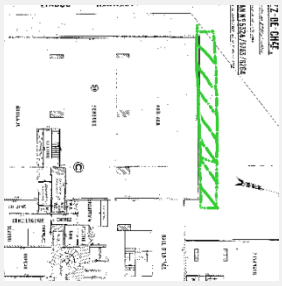
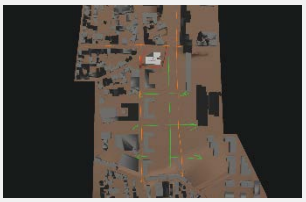
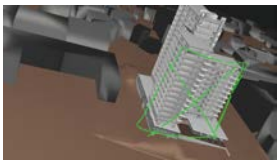
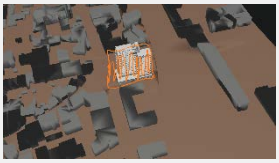
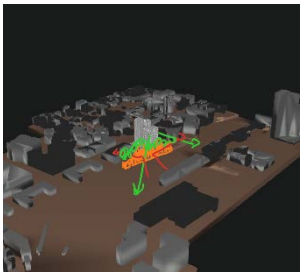
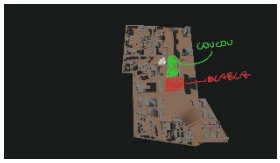
	PDF		
 Urban master plan	 Building master plan	 3D model	 Arch daily website link
 East façade photo	 West façade photo		
 South façade photo	 East façade drawing		
 Entrance hall elevators	 Ground floor plan		
 Elevator interior photo	 Third floor plan		
	 PLU Nancy		

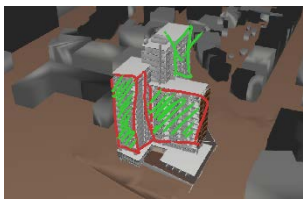
Table 16. Work documents and the collaborative tasks solutions propositions of the DSCW decision making session experiments.

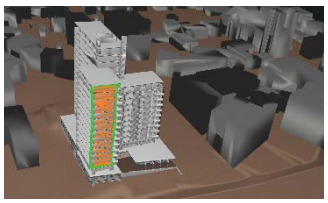
EXP	FCADE RENNOVATION SOLUTIONS	NOTES
	URBAN MASTER PLAN	o The schematic sketch annotations on the urban development plan are typical for an urbain scale discussions and work maps. o Large detailed documents are typical for an urbain project presentations o This documet represents an urbain context of the project, such a document would be always a good basis for project understand.
02	 	
03	  	
04		
	PLANS	
02	 	o Plans annotation in this case offers an view on a connaction between a exterior and interior of the building. o For some architects a plan would be a first document to put the ideas on.

03	 	
	3D MODEL	
01		o This kind of document gives a flexebility to the representation and visibility of the project o Urbain sketching annotations are even more visible on a 3D modlel due to the low level of the city blocks details, which reveals an essentials to the user witout any secondary details. o Multiple points of view and scale choices offer an opportynity to annotatate and create on a different levels of pression o Through the manipulations of the model several project problems were revealed, wich woud not be possible with a simple 2D plan of the project
02		
03		
04	 	

05

06





01

02

04

- 3D model is one of the most easily reading and understanding documents for any user.

- Façade pictures of the building were rather a good and more poplurar base for the propositions than a 3D model, such a picture doesn't quit the actual project environment context, wich leads to a certain simplicity of the ideas imagination.
- General idea not a true detail

05

02

04

ENTRANCE HALL RENNOVATION SOLUTIONS

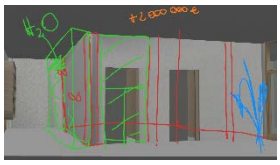
02

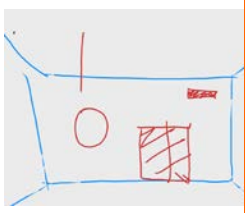
03

Visual connection between the documents simplifies the interpretation, understanding and use of the graphic infromation.

Some annotations are easier to make in a 2D plan than in the 3D model environment

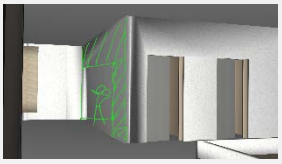
04

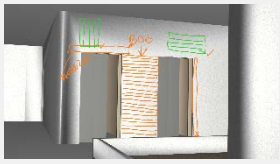




In a rare case not only the annotation but a drawing aside communicates the project ideas

05

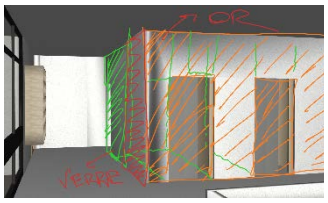




Schematic representation of a solution is enough to start a discussion and choose the futher development axis

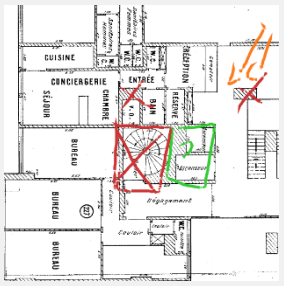
Numerous users can annotate the same document at the same time

06



After a general development axis dession sertain details might be defined immediately and their representation would ssure the clear understanding and communication.

03



Depending on a project development method certain parts of the project requier a 2D representation wich offers a good visibility of the space connections.

04

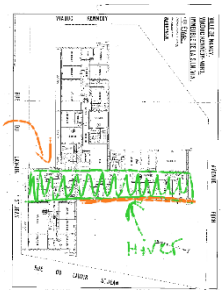


Table 17. DSCW decision making session experiment resume.

	KENNEDY TOWER DSCW DECISION MAKING SESSION EXPERIMENT						
SESSION	01	02	03	04	05	06	NOTES
PROJECT TYPE	Residential						o The same project and same tasks become a basis for the evaluation o The ESQ phase of development has less technical constraints than the following development phase, which offers a certain flexibility for a creativity session and decision making. o Different roles of the CS Actors reveal an additional competence brought in by professionals o Prepared in advance session did not require any additional devices o 3D model has enough information about the project to assure the Creative development; o Every session must have an access to the most important information about the entire project, not only the CS task related documents. o The basic package of information should content: master plan, GF plan, standard floor plan, cut-section, technical details, 3D model, exterior perspective views of the project, and depending on a development phase another legislative document related to the project.
PHASE	ESQ						
PROJECT CS AIMS	1. Creative development 2. Decision making						
EXPERIMENT AIMS	• To achieve the decisions making tasks • To test some possible uses for the digital synchronous collaboration sessions • To test and reveal the digital collaborative method advantages and limits • To find some potential development ways						
ROLES OF THE ACTIVE USERS	Architect Client	Architect Client Engineer	Architect Client Engineer	Architect Client Engineer	Architect Client HVACS engineer BIM manager Structure engineer	Architect Client	
KIT	• Wall + Shariiing • Table + Shariiing						
DOCUMENTS PREPARED FOR THE CS	• Urban masterplan (jpg) • Façades photos (jpg) • Entrance hall photos • Building master plan (pdf) • Facades drawings (pdf) • Floor plans (pdf) • Local urban development plan PLU (pdf) • 3d model (obj) • Arch daily website link						
SESSION PREPARATION	1. Objectives set. (Collaboration Manager) Collaboration Aim > Scenario choice, Actors, Time, and Place. 2. Documents preparation. (Collaboration Manager) Collaboration Aim + Actors > Documents choice & session preset upload 3. Session set ready confirmation. (Collaboration Manager > Actors)						o Preparation has an algorithm of actions. Without the preparation, a complex decision making session is not efficient. (In this case the preparation of the session contents was guided by the experiment preparations).

SESSION PROCEEDING	1. Informal part, greetings, settling. (Actors > Actors) 2. Session aim and contents presentation. (Collaboration Manager > Actors) 3. Problem solving. 1.1. Façade problem visualization. (Simultaneous display of the project documents: urban plan, façade pictures, 3D model) (Architect>Actors) 1.2. Creative sketching on existing documents (3D model view or a façade picture). (Architect>Actors) 1.3. Interprofessional discussion. (Verbal discussion + temporary annotations). (Actors>Actors) 1.4. Solution visualization. 3D model and plan annotation with the schematic representation of the solution, with additional dimensions' information. (Architect>Actors) 1.5. Interior problem visualization. (Simultaneous display of the project documents: GF plan, hall photos, 3D model) (Architect>Actors) 1.6. Creative sketching on the existing documents (3D model, GF plan, hall photo). (Architect>Actors) 1.7. Interprofessional discussion. (Verbal discussion + temporary annotations). (Actors>Actors) 2. Solutions evaluation. Discussion around the annotated documents. (Actors>Actors) 3. Resume, further development tasks. (Collaboration Manager > Actors)	o One person describes the project progress, problems, and session tasks. o Collaboration strategy and method depend on a task; o The actors choose the strategy according to the CS task, in general not officially, but in the process. o creative task engages a collaborative creative dialog and expresses solutions mostly with sketches; o The document choice depends directly on the Architects habits and methods of work o After the first task the CS achieves the second task with a higher level of confidence in DSCW use and the users' capacities to interact competently, than the first one.
CS REPORT	Feedback discussion. (Collaboration Manager > Actors)	
DOCUMENTS PRODUCED AT THE CS	3D model view annotation. Photos creative sketching 3D model view image creative sketches Plan annotations. Photos creative sketches .Photos annotations. 3D model view image creative sketches Plan annotations Photos creative sketches Photos annotations. 3D model view image creative sketches Plan annotations Photos creative sketches Photos annotations Sketch drawings. Text messages. 3D model view image creative sketches Photos creative sketches Photos annotations 3D model view image creative sketches Photos creative sketches Photos annotations	o Creative sketching is mostly used on the pictures of the project and 3D model views o Annotations appear on the plans and 3D models, when the presented information needs to be completed o Independent sketch drawings and text notes have been used for only one session mostly in discovery way than actual work application.

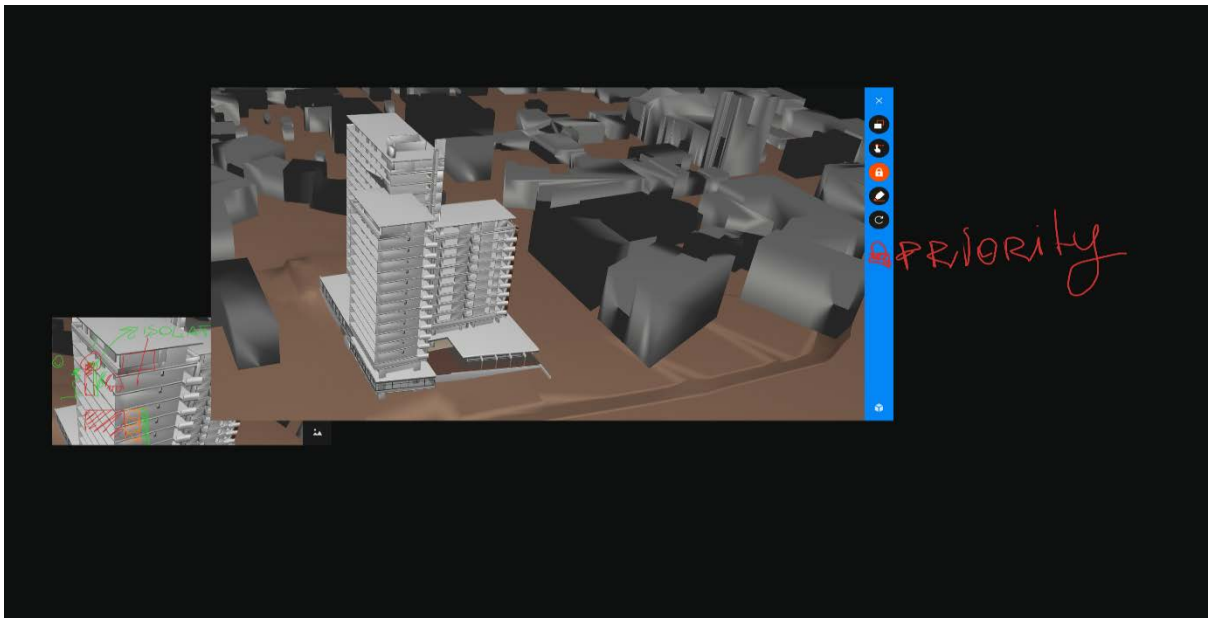
USERS OPINIONS							
WHAT IS MISSING AT THE DSCW?	•The basic pencil-case tools (marker, eraser, ruler…)	• Color choice • Distance collaboration module • Better touch gestures ergonomics	•3D navigation flexibility (Sketch up expl.) •Layouts for the annotation and sketching of all the documents, especially for the architecture plans •Vector graphics documents support	•3D navigation flexibility •Improved 3D interface •Layouts to replace the print screens •Navigation and manipulation ergonomics	•CS reports sender •IF file support •Layouts with annotation •Modification of the annotation •Annotation is available only on the documents but not really in the 3D environment of the 3D model •CS report screens video record with chapters corresponding to the task list and the voice records	• Frame control force button, to be able to stay at on display without necessity to return and unlock the frame on another screen when the sharing module is in use (Figure 37) • line type choice (Figure 41) • import/export document simplicity	• most of the critics is related to the annotation toolkit lack of instruments, navigation, and ergonomics improvement needs, and to the CS reports creation. • The most important problem is the navigation comfort level; users would not interact with the document if it is hard to manipulate • A pencil-case, line type choice and the layers have been traditionally a part of the AEC practices and their analog presence is crucial for the DSCW. • A high screen quality could assure the vector documents well detailed representation.
DSCW ADVANTAGES	•High quality of the project visualization •Discussion is supported by the graphic	•Practical tool for the modifications, quick corrections and discussions	•Interactivity and flexibility of the graphic information and the interface •Virtual work	•Good collaboration in a small group •Data contents concentration at the same work	•Simple appropriation and use •Group collaboration	•Same project image for the Architect/ Engineer or a Client •Improvement of the inter professio	• The most evident advantages are the quality of the document display, simultaneous visualization, and multi user touch screen guided interactions. • An additional value is the unification – all the document types at the same work environment follow the same logics, and

	info in parallel	•Decision making facility due to the quality information visualization	environment is relatedly complet	environment		nal dialog due to the quality of visualization and manipulation	a 3D model will give a same understanding scale to all the project participants
DSCW DISADVANTAGES	•Information gathering complexity •Too similar to a game tool.	the DSCW takes more attention than the project Equipment price	•Interface problems •Bad 3D navigation options •Self-closed work environment	•Software development and improvement requirements •Appropriation and confidence development time is too long •Equipment price	•Poor report information •Equipment price •Table screen resolution •General touch screen ergonomy comfort is low	•High detail level and full project details display may take the clients attention from the important questions and reduce the efficiency of the CS	• The technology and DSCW methods are relatively new to the public, so it takes time and an effort to concentrate on a task rather than on the equipment manipulation, and takes time to find an efficient way of expressions • Some of the software features require an improvement
Improvement proposition	1. Table might by replaced by some personal digital touch screen tablets to reduce the equipment price and put all the collaborative attention on the main screen. 2. Distant synchronous collaboration module would assure a gain of time, keeping the existing equipment configurations available at the co-working services.						
Observation	1. All the sessions begin with the all documents visualization, but the actual creation or decision comes from the annotation of only the one document representing the main idea, sometimes completed with another type of the information document annotation, such as 3D model view annotation + plan annotation. 2. The guiding session role is not permanent, and passes from one user to another trough the development on ideas and interventions. 3. An experienced professional is taking less time to achieve the task than their younger colleague.						
Conclusion	1. An efficient decision making and creative development collaborative sessions are possible with the existing sets od the DSCW. However, a certain technical improvement and tools development should be preceded to achieve the addition of the new values for the digital synchronous collaboration. 2. The DSCW use is simple enough to make the users fill confident in their tools manipulation skills, so the lack of a						

DSCW use experience has no influence on the collaboration process.

3. The collaboration session must be concluded with the clear results and session report representation.

Figure 37. Shariiing 3D frame annotations with a sharing module, case of the priority manipulations button necessity.



4.7. DSCW AND THE ONGOING PROJECT OF THE ARCHITECTURE AGENCY COLLABORATION CASE EXPERIMENTS.

Tree different architects interested in the development of the technologies and collaborative techniques have participated in the collaborative sessions brining their ongoing projects as a material for a collaborative session. All the three whom have their own methods of work:

Active use of the sketches and hand drawings to create, develop and communicate the project, and the CAD tools to develop and build the project, without BIM methods integration.

Rare use of the hand sketches and drawings, the project development is assisted with the CAD tools, but without need of the collaboration or BIM methods integration. Rare use of the hand sketches and drawings, the project development is assisted with the CAD tools and implementation of the BIM methods.

Such a diversity of the project development and tools implication approaches would assure a comprehensive evaluation of the DSCW (Table 18. Resume of the ongoing project of the architecture agency collaboration case experiments.), and the adaptation abilities and flexibility of the current architecture project development practices.

Figure 38. Senior Residence passivhaus session experiment.

1. SINGLE FAMILY HOME SESSION EXPERIMENT.

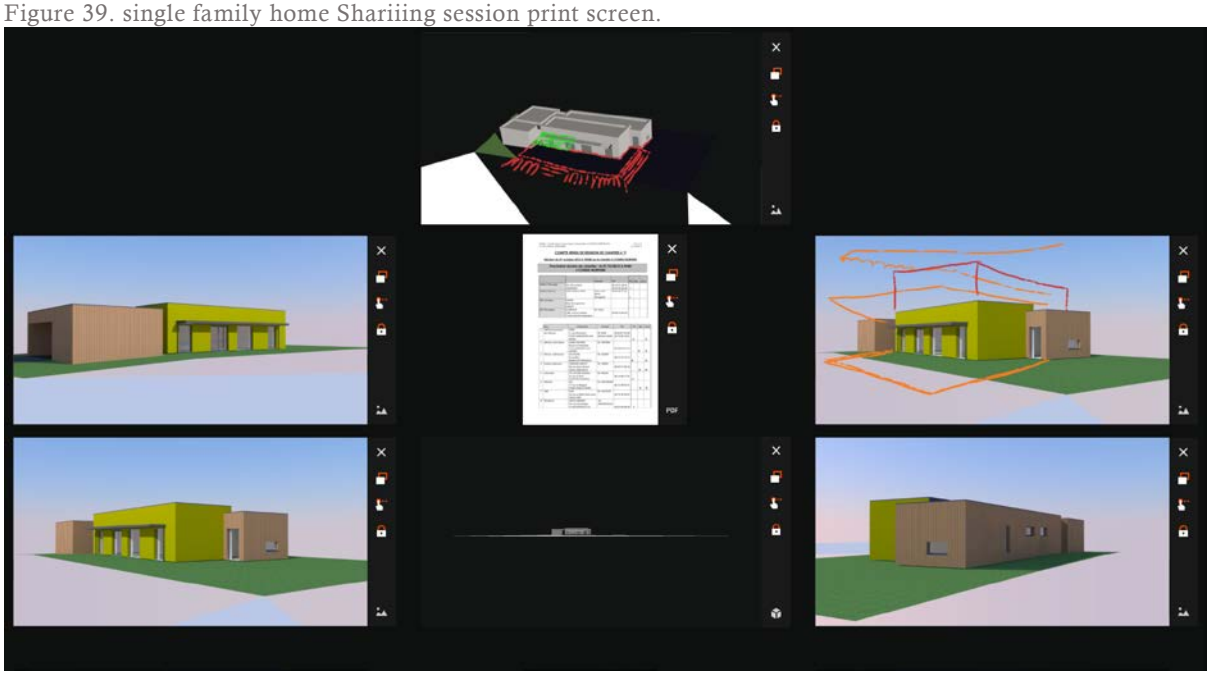
The first project of SARL Manon KERN was a project of a single-family home at Conde-Northen. The project was already constructed and delivered, but on a certain development stage there was a possibility of the developing a terrace and an additional second level. The collaborative session aimed to decide about the project using the DCSW and to evaluate an efficiency of such collaboration method.

The experiment participants took an architect and a client's roles. (Manon Kern – an architect, Veronika Bolshakova architecture graduate student). Following project information was uploaded to Shariiing: textured 3D model of the project, 4 perspective pictures of the model, a pdf document with some information about the project.

The first part of the session was about a small project presentation and the 3D model manipulation to have a clear view of the project. And the second part included a discussion and 2D sketch-annotations on the 3D model capture and on the one of the perspectives images (Figure 39).

At this experiment the decision-making task was accomplished without any particular difficulties. And the efficiency of work was supported by only two types of documents: the 3D model and annotated image captures of it.

Figure 39. single family home Shariiing session print screen.



2. SAINT DIZIER STREET RESTAURANT SESSION EXPERIMENT.

The second project of Alain Fuchs Architect was a project of a restaurant situated on a Saint Dizier street (one of the main commercial streets with a historical value) in Nancy. The project is currently in a conceptual development, and consists of a design of a new vitrine-façade for the restaurant. The particular condition is to ensure a consistency with the historic facades around the restaurant building. The collaborative session aimed to make a decision about the project using the DCSW and to evaluate an efficiency of such collaboration method. An architect and a client's roles were taken by the experiment participants. (Alain Fuchs – an architect, Engueran Merz – graduate architecture student). The textured 3D model of the project was a collaboration session material only document.

The first part of the session was about a small project presentation and the 3D model manipulation to have a clear view of the project. And the second part included a discussion and 2D sketch-annotations on the 3D model capture with a proposition of two possible solutions for the façade renovation.

Only one 3D model was enough information to choose a project development axis and to be a base for the sketches (Figure 40). Such unification of the represented information lets better concentrate on a decision and visualizes in the same way the differences between the proposed façade solutions. Collaborators are concentrated on a major decision and manipulate only one document.

Figure 40. Restaurant Saint Dizier Str. Shariiing session print screen.

3. SENIOR RESIDENCE PASSIVHAUS SESSION EXPERIMENT.

The third project of SARL of Architecture Mil Lieux was a project of a senior residence labeled Passivhaus[3], situated at Art-sur-Meurthe. The project is currently in a final stage of the conceptual development AVP (Etudes d'avant project), and consists of a design of a new housing building for seniors, with a particular ambition to be labeled as a Passivhaus building. The collaborative session aimed to make a decision about the water pipes supply system for the project using the DCSW and to evaluate an efficiency of such collaboration method.

This collaborative meeting was about taking a real decision about the father project development, so the roles during the collaborative session corresponded to the real professions of the participants: architect – Jean-Philippe Donzé, client – OPH Nancy represented by Elise Ringard, HVACS[4] consulting engineers Louvet – Pascal Bresso, and a consulting BIM manager Olivier Celnik (Architect d.p.l.g.[5]) (Figure 37).

The textured 3D model of the project and a pdf document with the master plan, GF plan, apartment types, cross-section and detail of a cross section were uploaded to Shariiing as a collaboration session material. However, only the 3D model and a GF plan zoom image were used for the decision making and annotations.

All the members knew well enough the project, so the session documents presentation wasn't necessary. So, the users have passed directly to the discussion with a help of some 2D sketch-annotations on the 3D model capture and in a same time on a part of the GF plan (Figure 42).

[3] Passivhaus buildings provide a high level of occupant comfort while using very little energy for heating and cooling. They are built with meticulous attention to detail and rigorous design and construction according to principles developed by the Passivhaus Institute in Germany, and can be certified through an exacting quality assurance process. (Passivhaus, 2014).

[4] Hydraulic, ventilation, Air-conditioning, Sanitary.

[5] Architecte diplômé par le gouvernement.

The 3D model was a base for the sketches, but in a case of this session aim required a certain level of precision, so in addition to the 3D model, right next to it was displayed a detailed plan of the building, and annotated at the same time the model. So, the discussion visual supports took “two dimensions” a 3D with the model, and a 2D with the scaled plan of the building. The objective of the collaborative session was achieved, but not in a fully satisfying way because of the lack of dimensioning instrument. The main decision was taken, but without some conceivable additional precise details.

Figure 41. Shariiing 3D frame annotations – case of the different line types requirement.

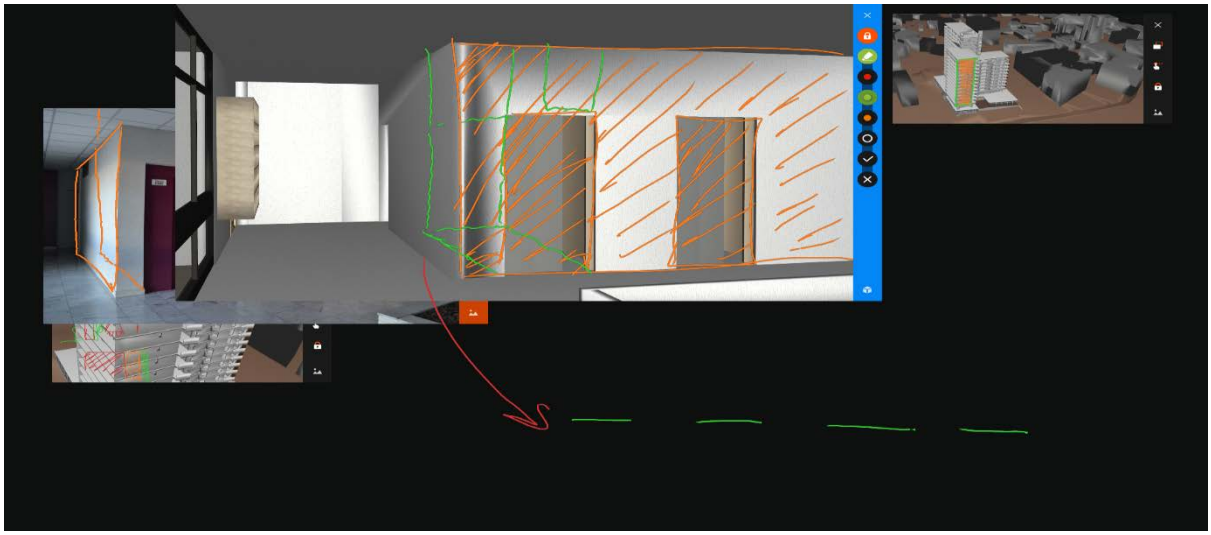


Figure 42. Senior Residence passivhaus Shariiing session print screen.

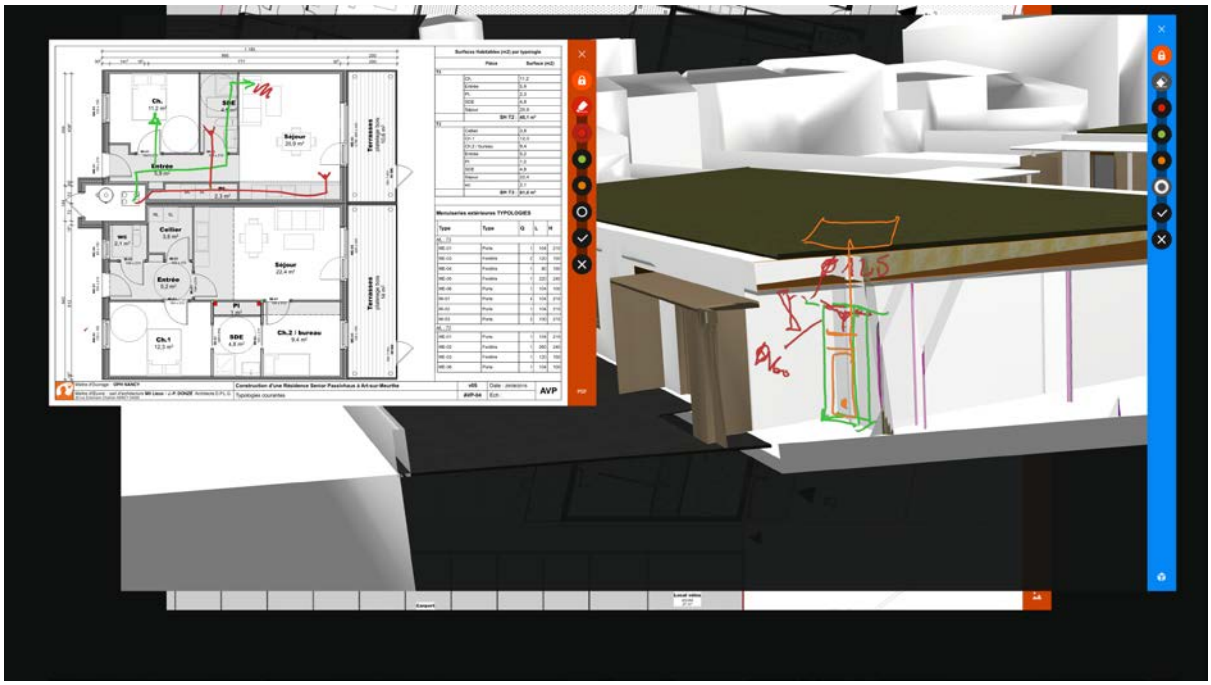


Figure 43. Architect M. Donzé annotating the GF plan section on the Wall.

Table 18. Resume of the ongoing project of the architecture agency collaboration case experiments.

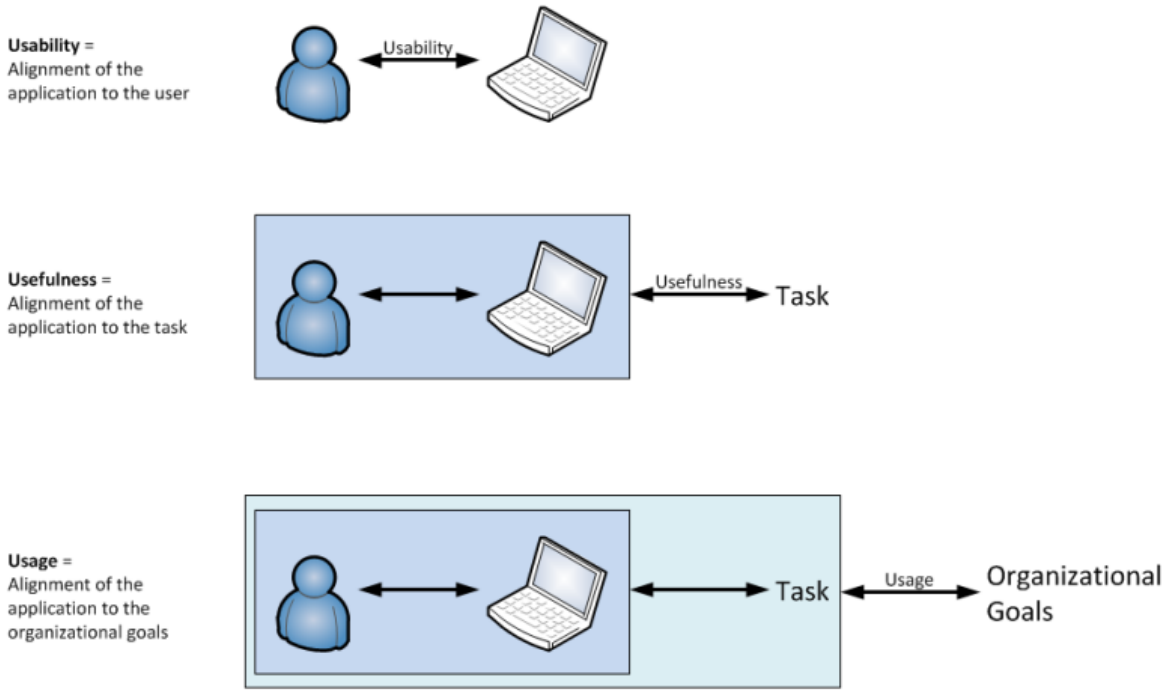
SESSION	SINGLE FAMILY HOME	ST DIZIER RESTAURANT	SENIOR RESIDENCE	NOTES
PROJECT TYPE	Residential	Public	Residential	o Any project type on any development stage can be brought to the DCS, on a phase ESQ the dialog is only an architect-client, and involves mostly the creative development with the WALL+TABLE; o AVP+ development phase involves a group of professionals into the CS and requires an addition of the PC with the specific professional software.
PHASE	ESQ	ESQ	AVP	
PROJECT CS AIMS	1. Creative development 2. Decision making	1. Creative development 2. Decision making	7. Decision making	
ROLES OF THE ACTIVE USERS	• Architect • Client	• Architect • Client	• Architect • Client • HVACS engineer • BIM manager	
KIT	• Wall + Shariiing • Table + Shariiing	• Wall + Shariiing • Table + Shariiing	• Wall + Shariiing • Table + Shariiing • Laptop + Shariiing sender	
DOCUMENTS PREPARED	• 3d model (obj) • Perspectives (jpg)	• 3d model (obj)	• 3d model (obj) • Master plan (pdf) • Gf plan (pdf) • Apartment type plan (pdf)	o 3D model has enough information about the project to assure the Creative development; o DM session with the AEC professionals

FOR THE CS			• Cut section (pdf) • Cut-section details (pdf)	needs the precise documents, (plans and cut-sections).
SESSION PREPARATION	11. Objectives set. (Session initiator > Collaboration Manager) Collaboration Aim > Scenario choice, Actors, Time and Place. 12. Documents preparation. (Actors > Collaboration Manager) Collaboration Aim + Actors > Documents choice & session preset upload 13. Session set ready confirmation. (Collaboration Manager > Actors)			o Preparation has an algorithm of actions. Without the preparation a complex decision making session is not efficient.
SESSION PROCEEDING	14. Informal part, greetings, settling. (Actors > Actors) 15. Session aim and contents presentation. (Collaboration Manager > Actors)			o CS is a part of social human interactions, informal part is important for the collaboration mood o One person describes the project progress, problems and session tasks. o Collaboration strategy and method depend on a task; o creative task engages a collaborative creative dialog and expresses solutions mostly with sketches; o A simple task requiring an intervention from number of professionals creates a complexity of collaboration and a very detailed project representation.
	16. Problem solving. Annotations + discussion > sketching solution propositions. (Architect> Client) 17. Solution evaluation. Annotations + discussion. (Client > Architect)	6. Problem solving. Annotations + discussion> sketching solution propositions. (Architect> Client) 7. Solution evaluation. Annotations + discussion. (Client > Architect)	6. Problem solving. 6.1. Problem presentation. Annotations of the 3D model view IMG. (Architect>Actors) 6.1. Interprofessional discussion. (Actors>Actors) 6.2. Solution visualization. 3D model and plan annotation with the schematic representation of the solution, with additional dimensions' information. (Architect>Actors) 7. Solution evaluation. Discussion around the annotated documents. (Actors>Actors)	
	18. Resume, further development tasks. (Collaboration Manager > Actors)			o CS final point closes the session, and the report is imperative
CS REPORT	19. CS materials and report share. (Collaboration Manager > Actors)			
DOCUMENTS PRODUCED AT THE CS	1. 3d model view image creative sketching 2. Img of perspective creative sketching	1. 3d model view image creative sketching	1. 3d model view image project information annotations 2. Plan img project information annotations	o 3D document annotation assures the clearest representation of the project. 6. Plans/cut-section annotations are fundamental at interprofessional dialog

Architect profile			
experience	16	7	21
Hand drawings and sketches use	Active use to create, develop and communicate the project	Rare use, project development axis definition	Rare use
CAD use	Project plans/cut-sections/details development, construction documents	Project conception, plans/cut-sections/details development, construction documents	Entire project development
BIM use	No	No	Yes
Distance collaboration	No	No	Rare
DSC advantages	Visualization	Flexibility and graphic interactivity	Simple in use, collaboration possibility
DSC disadvantages	Information assembling complexity	Interface problems, laborious 3D model manipulation	High equipment price, the gap of session recording
Observations	1. With their own projects on the table the Architects were showing less confidence in their decision making abilities, but stood confident in their DSCW skills. 2. Documents display takes time in the beginning, as well as the annotations and sketching, but the majority of the session time was spending in a discussion about the solution. 3. A 3D model and a plan represent an essential for any project understanding, so a detail quality of the both documents has to be as developed as possible.		
Conclusions	1. An efficient CS is possible with the current DSCW setups. 2. A new level of the visualization and interactions indeed offers an additional value to the collaboration quality. 3. Most of the session had an architect in a central role of the CS, which is typical for the ESQ phase of development, and adds unofficially a task of the collaboration coordinator to the architect. 4. The DSCW unites well in a collaborative environment a group of participants, creating a unity of the group. 5. DSCW reveals more advantages in collaboration for the projects containing a well-developed 3D models.		

4.8. ANALYSIS AND EVALUATION.

Figure 44. Usability, Usefulness, Usage diagram. (Delft University of Technology in Delft, The Netherlands, 2016).



The useful product will accumulate the best qualities of its usability (how easy and agreeable the features are in use) and usefulness (whether it provides the required features).(UsabilityNet, 2003). So, the usage would answer to all the requirements and assure an agreeable comfort level of use.

The experiments have gathered enough information to give an evaluation to the DSCW, paying attention to the criterias of usability[6], usefulness and usage (Figure 44) applied for the collaboration case, and introduce some critics and suggestions to the AEC industry implementation of the tool with the method. Experiments observation and a questionnaire (Sections: 1. Session information, 2. User profile, 3. Usual work methods, 4.

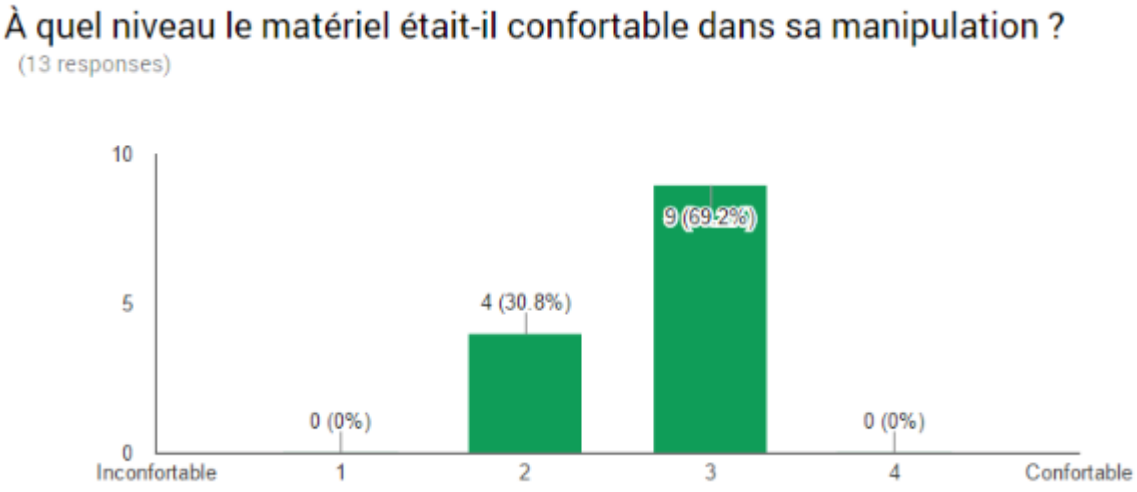
[6] The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use. (UsabilityNet, 2003)

Experience results, 5. Further development) represent the basic information to evaluate the usage.

On the questionnaire section 4. Experience results, with the questions from 17 to 29 the experiment participants were asked to give their opinion on a session result, equipment comfort in use, and also the DSC method evaluation. (Annex I. DSCW experiments questionnaire.).

5 from 13 of the users confirmed them for them an interest of the method wasn't clear before the experimentation, but after the experimentation all the users have confirmed that they could see it after the session (except one user), all the users have agreed that the collaboration task was accomplished and that the equipment is rather easy than difficult in use, but the comfort of the use was not judged as a high but rather acceptable. (Figure 45.)

Figure 45. Equipment comfort in use level.



The 80 % of the user have found the method incomplete and gave their opinions about the missing elements, advantages, and disadvantages of the method. (Questions 22,23,27,28). Based on the results the DSCW usability resume was composed. (Table 19).

In addition to the DSCW usability overview the collaboration and interactions tells about the digital collaboration as a method of the AEC project development. (Table 20). And of course,

apart the method implication, the project itself defines the whole session contents and development. (Table 21).

Table 19. DSCW Usability resume.

DSCW USABILITY			
LEARNABILITY	• Basic tasks are easily accomplished by al the users the first time they try.	Good	The usability evaluation stands rather to the acceptable point, the DSCW can still be used, providing an acceptable environment for the collaboration, but has to be adjusted to the AEC requirements
EFFICIENCY	• After the training session users achieve the task solving on a first or a second tries.	Good	
MEMORABILITY	• Returning to the DSCW users have some difficulties using the system, and have to take their time to remember the procedures and regain a confidence	Bad	
ERRORS	• In general, the error is made due to a wrong manipulation and easily corrected	Acceptable	
SATISFACTION	• Most of the users found the DSCW completely functional but not very ergonomic or intuitive, thus some of the interactions require a manipulations reading improvement and development of the new additional tools and options.	Bad	

Table 20. DSCW method practice resume.

DSCW method practice		NOTES
USER/EQUIP. INTERACTIONS	Al the users implied the basic manipulation gestures (move, rotate, scale) and the inside frame manipulation gestures actively, the equipment became a real work field, and created also a connection between the Wall and the Table.	The method inherited all the previous collaborative practices features adjusting them to the technical specifics and interaction gestures
USER/EQUIP. USAGES	Not all of the equipment usages were useful during the collaboration (print screens, web sites, text notes, videos, temporary annotations, stream share, have not been in a large use), but the lack of usages was not a good influence on the session efficiency.	
USER/USER INTERACTIONS	Users tend to start a more active discussion around the annotated document, every collaborator knows his role in the session, and there is usually an architect leading the session. Often the	

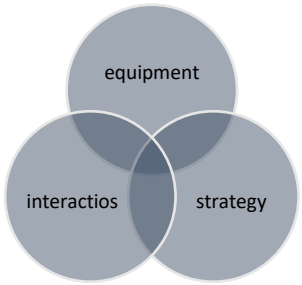
	communication passes through a cycle Individual expression > common discussion > individual expression.
USER/PROJECT STRATEGY	User tend to display all the project contents to have a global view, identify the tasks and documents to work with, and starting by the most important task they are manipulating the documents with a best visibility of the task problem. The solved tasks appear on the Wall as a report and a reminder.
FACTORS DECISION MAKING	To get the decision collaborative approve from the users, and will have to assure a clear presentation and visibility of the solution, a possibility of the group discussion with a final point.

Table 21. Project content and the DSCW.

PROJECT PARMETER	Influences	NOTES
PROJECT TYPE	The scale, development strategy, actors involved	These are the most important parameters and their dependents which might change the global project collaborative strategy.
PHASE	The definition of details, priority tasks, actors involved	
SCALE	The document contents, detail level, recourses investment	
CONTEXT	Specific requirements and tasks, specific competences	
DEVELOPMENT METHODS	The workflow contents, tasks managements, decision making strategy	

Nevertheless, the quality in use would vary from the project to project, collaboration session embers, and the tasks to achieve. And the quality of the collaboration session will always stand on an equipment(functionality, reliability, usability, efficiency, maintainability, portability, (*ISO/IEC FDIS 9126-1: Software Engineering - Product quality - Part 1: Quality mode*, 2000), on the interactions, and on the project approach strategy. (Figure 46).

Figure 46. DSCW session evaluation segments.



CHAPTER CONCLUSIONS.

For a majority of the AEC professionals the digital collaboration technologies are not a part of the everyday practices, and digital synchronous collaboration is a new method to discover for them as well. The new collaborative work environment confronts the existing methods against some new challenges. In this situation, the methods have to adapt, and create the new work protocols.

Unfortunately, a simple non-digital orientated methods implementation at the DSCW session (without an adaptation) won't provide any other additional value to the collaboration, except an excellent information visualization quality. So, an adaptation of the methods and practices is a key to the efficient digital collaboration. Renewed methods and an implicated team work provide good results, and the collaboration session gains an additional value to the collaboration quality. For a full confidence and professional use of the DSCW the tools, as well as some specifics of the method must be well understood and applied during the appropriation séances.

The further technical capacities development with some new instruments and features addition will be absolutely necessary for the further study of the method, the research, and of course the AEC industry implementation

5. INTERNSHIP OVERVIEW.

5.1. EDUCATION AND RESEARCH CONTEXT.

The present research was made during the internship at the research laboratory MAP-CRAI (Centre de Recherche en Architecture et Ingénierie, which is a part of "Unité Mixte de Recherche-Modèles et simulations pour l'architecture, l'urbanisme et le paysage") as a part of my course at École Nationale Supérieure d'Architecture de Nancy for a diploma of an architect "Diplôme d'État d'Architect" (DEA) and a Masters diploma at "Design global spécialité "Architecture Modélisation Environement" (AME), aimed to complete the received theoretical school knowledge with some practical experience in the research field.

Numerous researches were performed at the laboratory previously to study the subjects of coordination, collaboration and communication efficiency at the AEC industry. (Olivier Malcurat, Spécification d'un environnement logiciel d'assistance au travail collaboratif dans le secteur de l'architecture et du B.T.P. ENSAN, 2002; Damien Hanser, Proposition d'un modèle d'auto-coordination en situation de conception, application au domaine du bâtiment. Octobre 2003, ENSAN; Sylvain Kubicki, Assister la coordination flexible de l'activité de construction de bâtiments. Une approche par les modèles pour la proposition d'outils de visualisation du contexte de coopération. Novembre 2006, ENSAN; Annie Guerriero, La représentation de la confiance dans une activité collective. Application à la coordination de l'activité de chantier de construction. Avril 2009, ENSAN).

5.2. INTERNSHIP SUBJECT AND PROBLEMATICS.

The internship research subject about synchronous collaboration and 3d interactions was dedicated to study the new equipment for a digital collaboration and developing some hypotheses of its usage, and also its proper adaptation to the requirements and particulars of the AEC industry, and as well some communication and a product feedback on the Immersion software and hardware products. Among the collaborative purposes of the equipment there is a possibility of an immersive interaction of the user with the 3D models. My colleague Guillaume Hanquet has been developing his internship subject around the theme of the interactions and annotations of 3D models and their implementation into the usage of the collaborative workspace equipment at MAP-CRAI. (Figure 10). The research

problematic wat about setting up the digital synchronous collaboration workspace, styling an existing research and solutions in the field, providing an observation and feedbacks with the equipment developers, testing some collaborative scenarios and analyzing their results to conclude a possibility of the appropriation of the DCSW by the AEC professionals.

So, a part of the internship was dedicated to an appropriation with the equipment (The Wall and the Table, Shariiing, Shariiing Widget), finding bugs and correct settings, usage ways. Another part was about analyzing some already existing scientific researches about the subject. Also, as an experimental part, various tasks were performed: communication and brief demonstration of the DSCW abilities, tests and experimentations with some students and professionals of architecture.

5.3. ORGANIZATION AND SUPERVISION.

The research development has been assured by the help from the team of the Map-CRAI. Two supervisors Gilles Halin (scientific director of MAP-CRAI, co-director of l'UMR n°3495 CNRS/MCC) and Pascal Humbert (researcher at MAP-CRAI, in charge of the "Visualisation et Interaction dans les Espaces Virtuels" axe of the research) have been tutoring and guiding me at my work, and developing the research subject as well too. Some guidance and advices were as well offered by another members of the laboratory - PhD student Henri-Jean Gless about a team productivity and meetings organization, technical support manager Vincent Marchal about a computer system setup, associated researcher Mohamed-Anis Gallas about some specific requirements of the collaboration around the non-standard architecture projects, and also a researcher from the LIST (Luxembourg Institute of science and technology) Annie Guerriero about collaboration scenarios at the AEC industry and scenario's experiments observations.

To keep all the information collected and developed during the research I've decided to use the Google Drive (Figure 46) and Google Documents tools. A journal of the research contains a list of the day tasks, notes about performed research, links to the articles, observations, and reports (Figure 47). A long-term project development organization and results visualization was tempted to be developed with a help of the Trello online task management tool (Figure 48). Zotero Standalone software was used gather and organize

consulted sources of the research, as well as a MS Word and Chrome internet browser Zotero plugins. Also, to organize a good visibility for all the tasks to do for all the members of the project development there was a test of Todolist task organization platform.

The internship started on the 16th of February 2016 and lasted till the 5th of September on a half-part time contract terms. Every two-three week during the internship I had the development progress meetings with my supervisors, letting to keep the right direction and main tasks of the further development. Numerous visitors (architecture and engineering students, researchers, architects, ENSAN professors and administrative stuff, AEC project developers, open doors day visitors, etc.) have participated to a brief demonstration of the DSCW and Shariiing, and about 10 have kindly dedicated theirs's time to a participation at the collaborative scenarios experiments.

Figure 47. Google Drive folders for the internship information gathering and development.

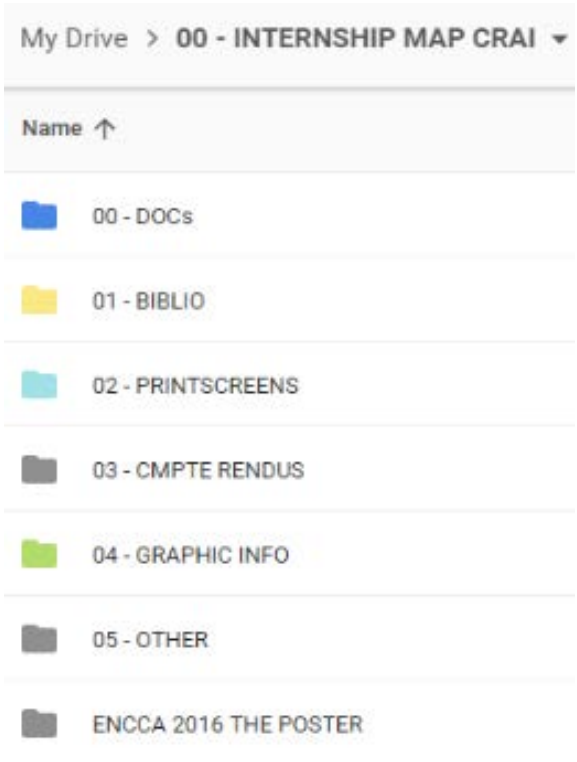


Figure 48. Journal of the internship on Google Documents.

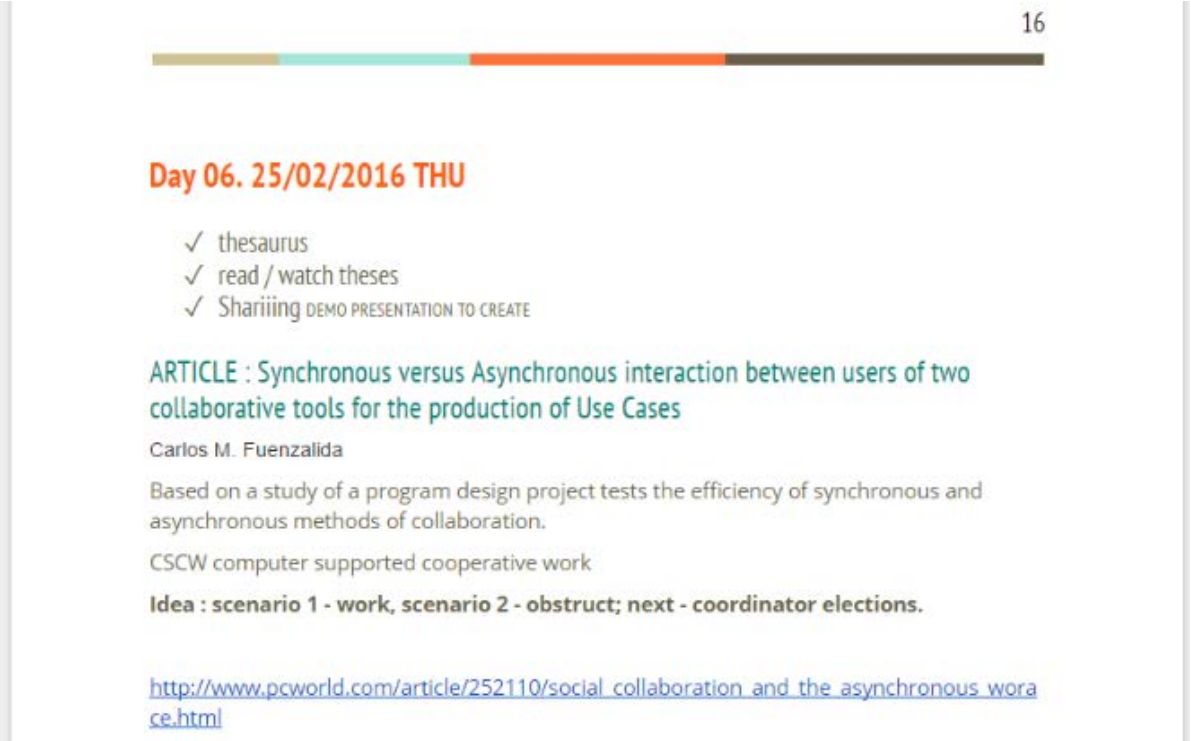
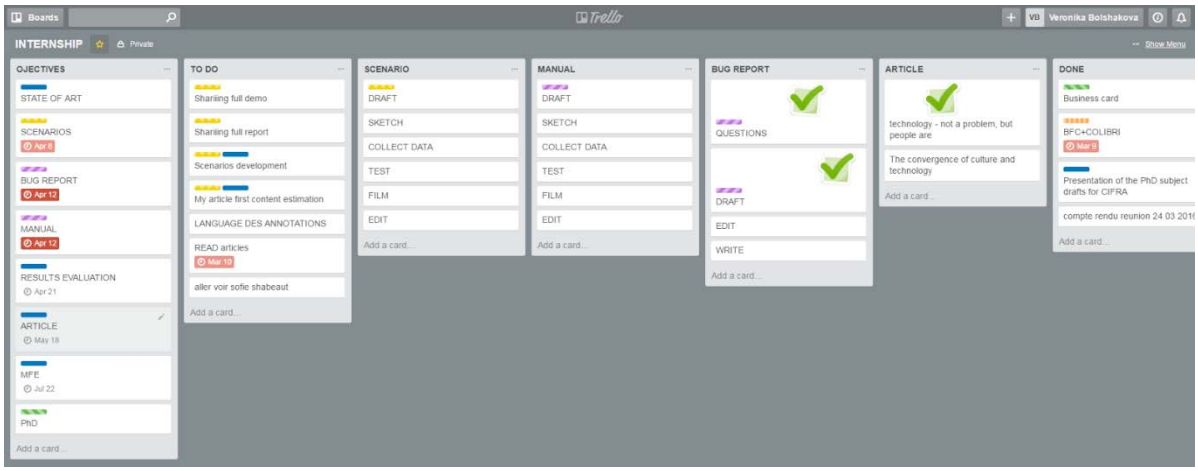


Figure 49. Trello task management internship aims board.



CHAPTER CONCLUSIONS.

Such an internship has offered me a very interesting research experience, a collaboration, and a possibility to lean from the professional research team, to reveal and to take a closer look at some of the contemporary problems in the AEC domain, and, also, to find and develop some hypotheses about the further implementation of the digital collaboration tolls and methods into the AEC practices.

6. CONCLUSIONS.

COLLABORATION PROCESS COMPLEXITY.

Collaboration as a social event could be described with a vast complexity of fragments, to many factors and parameters are participating in a creation and a definition of this process. But when such a proses becomes a professional task with a strong aims and objectives, mutual and individual responsibilities all the collaborative interactions have to be optimized.

The maximum efficiency exchange is a key for the effective collaboration session. To achieve this, aim the collaborators might address themselves to the last technology solutions, to be able to augment the project visibility, simplicity of understanding, and as well unite all the information at the same interface and manipulate it together.

TECHNOLOGY BRINGS A CHANGE.

Any new technology come always bring some complication in a first place, because of a need for a change of the existing order of processes and protocols. The pioneers and innovators are seeking for the evolution. A professional, to imply the innovative solution into the everyday well tested and known practices, will have to take a risk to succeed in his ideas realization, and risks are not always obvious consequences of a change to confront when the project development is on question. A proper motivation, appropriation, confidence development and the use methods development should first take a place as a first step to get efficient and performant with the innovations.

I reason, that the digital collaboration progress is already in use by a certain large scale companies, their experience of the DSCW use and the provided experiment sessions prove that such a technology brings an additional value to the collaborative process. The presented methods show the potential of the digital collaboration with BIM as well as the new methods for discussion meetings around a virtual 3D model. DSCW increases the precision in communication.

AEC industry is on a phase of transition to the common use of the 3D models and BIM methods of the project development, such a change of the basic work document will require a change of the document presentation method. In a digital collaboration space with

a clear and detailed visualizations of the 3D models all the professionals would have a same project display, and an interactions gestures to manipulate the project information.

ADAPTATION TO THE DIGITAL COLLABORATION METHODS BY THE AEC INDUSTRY PROFESSIONALS AND DIGITAL COLLABORATION METHODS ADAPTATION TO THE SPECIFICS OF THE AEC INDUSTRY.

When the digital technology of the project development is already in use, it is time to search an efficient digital collaboration method for the AEC industry. However, the presented DSCW methods current state requires a lot of further research, development and testing. The technology didn't develop yet some specific features, typical for the AEC industry project development tools. The following development step will be the implementation of the user requests and a further evaluation of the digital synchronous collaboration workspace performance.

The future work should be focused on a technical improvements research: manipulations ergonomics, navigation simplicity, additional tools, and instruments development; and also, focused on a development of the collaborative method protocols and uses according to the project phase of development and the project contents.

The digital collaborative workspaces technology implementation and current tests by some professionals will raise the future standards and certainly arouse a wider implementation into the collaborative practices at AEC industry.

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TABLE OF FIGURES.

NOMENCLATURE

CS – Collaboration session

DCW – Digital collaboration workspace

DSCW – Digital Synchronous collaboration workspace

AEC – Architecture Engineering Construction

PC – personal computer

DM – decision making

CAD – Computer Aided Design

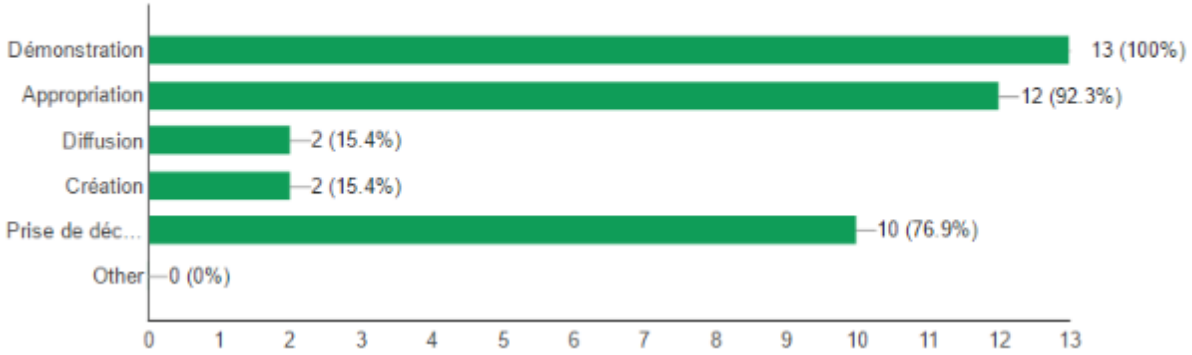
ANNEXES

ANNEX I. DSCW EXPERIMENTS QUESTIONNAIRE.

https://docs.google.com/forms/d/1UuzCzNRsV7m5AaBq6ranEIKFRLmx6RD7Vo4rTokp02w/prefill

1. Quand s'est déroulé votre session ? (6 responses)

2. Quel type de Scénario avez-vous expérimenté ? (13 responses)



3. Combien y avait-il de participants ? (13 responses)

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3
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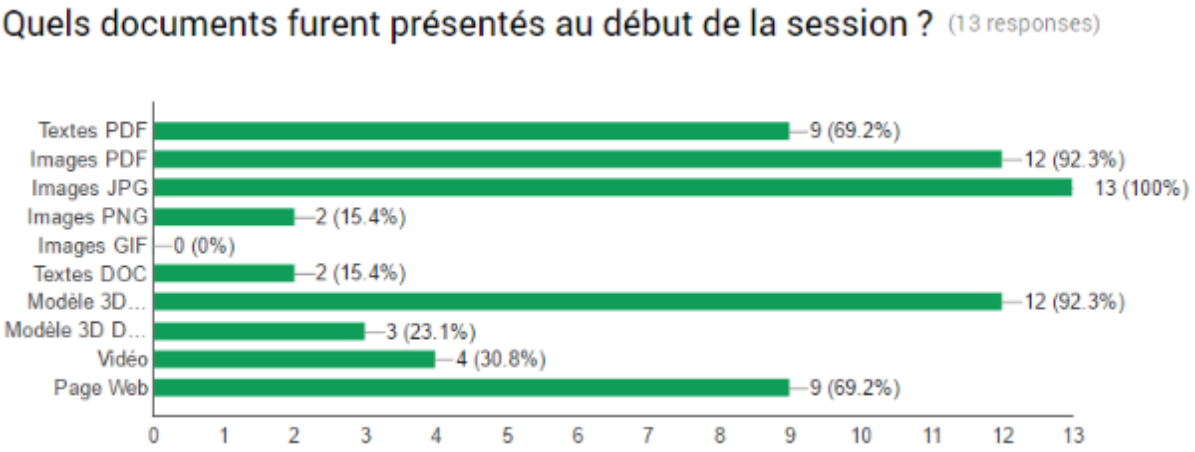
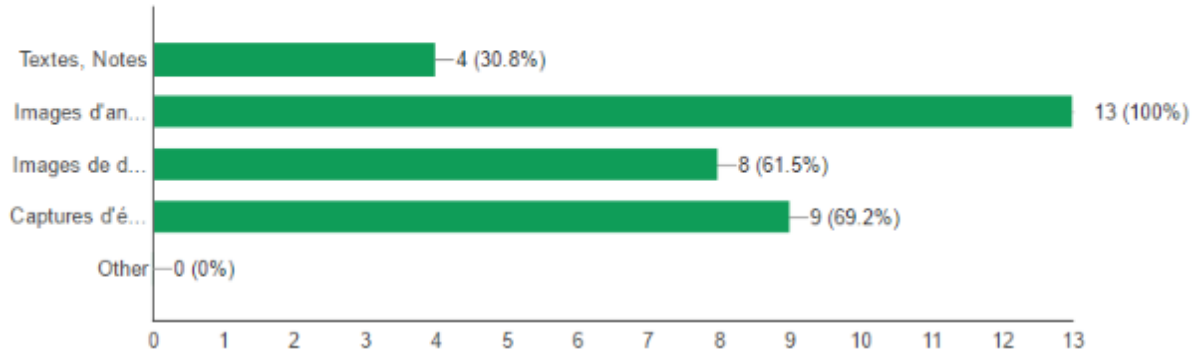
3
3
2
2
2
2
6
6
4
5

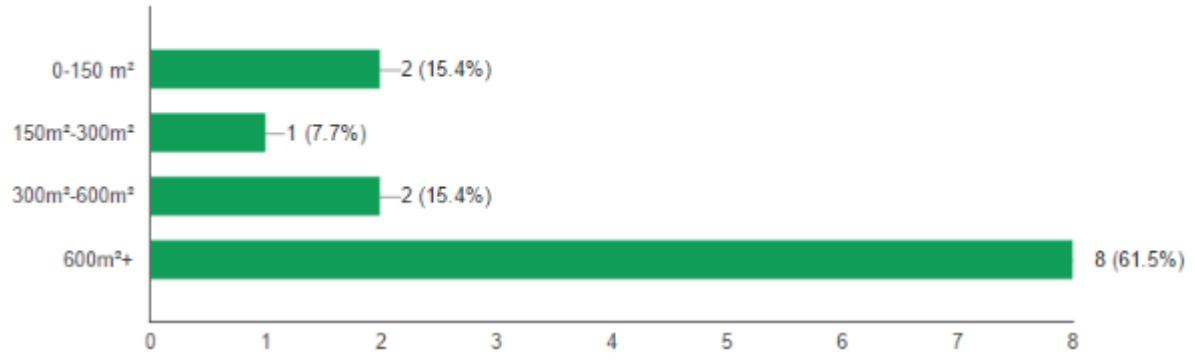
4.


Quels documents furent présentés au début de la session ? (13 responses)
Textes PDF
Images PDF
Images JPG
Images PNG
Images GIF
Textes DOC
Modèle 3D...
Modèle 3D D...
Vidéo
Page Web
9 (69.2%)
12 (92.3%)
13 (100%)
2 (15.4%)
0 (0%)
2 (15.4%)
12 (92.3%)
3 (23.1%)
4 (30.8%)
9 (69.2%)
0 1 2 3 4 5 6 7 8 9 10 11 12 13

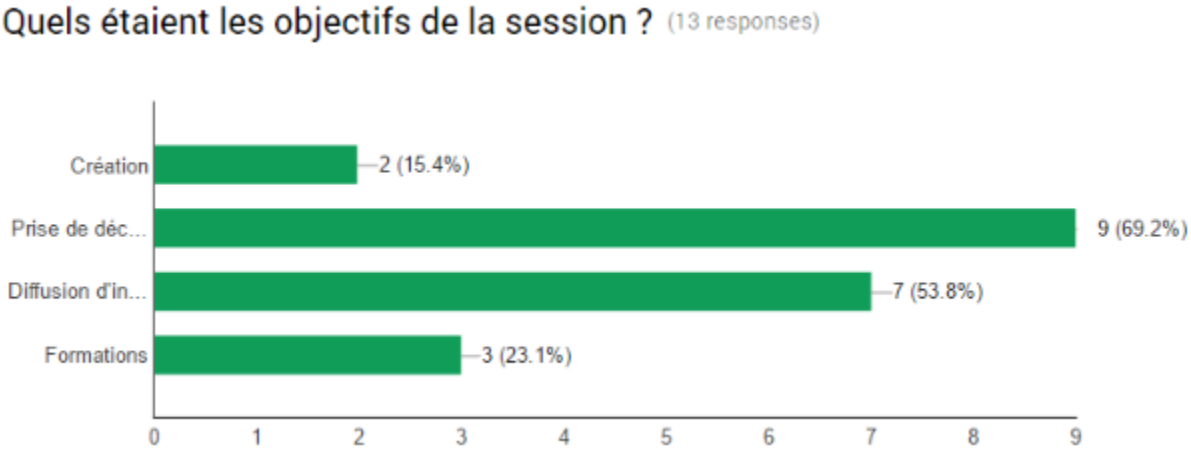
5.


Quels documents furent produits pendant la session ? (13 responses)
Textes, Notes
Images d'an...
Images de d...
Captures d'é...
Other
4 (30.8%)
13 (100%)
8 (61.5%)
9 (69.2%)
0 (0%)
0 1 2 3 4 5 6 7 8 9 10 11 12 13

6.

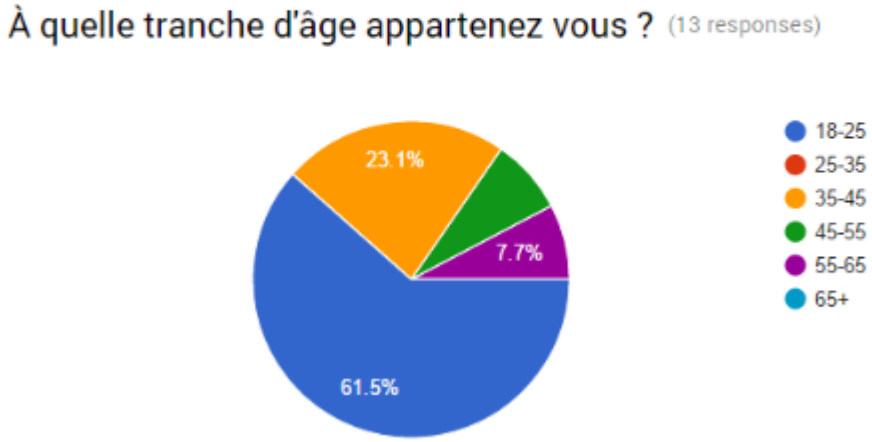

Quelle était la surface du projet ? (13 responses)
0-150 m²
150m²-300m²
300m²-600m²
600m²+
2 (15.4%)
1 (7.7%)
2 (15.4%)
8 (61.5%)
0 1 2 3 4 5 6 7 8

7.

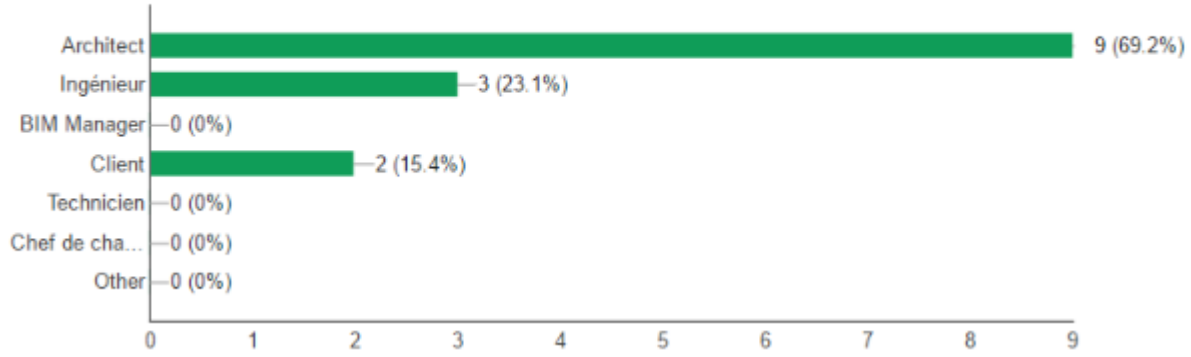


8.

Utilisateur

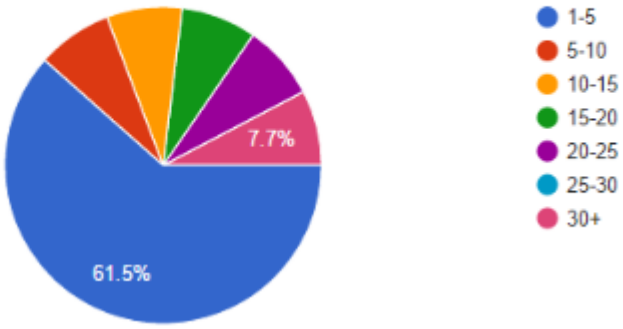


9.



10.

Depuis combien de temps pratiquez vous ? (13 responses)



11.

Dans quel pays exercez vous principalement? (13 responses)

France

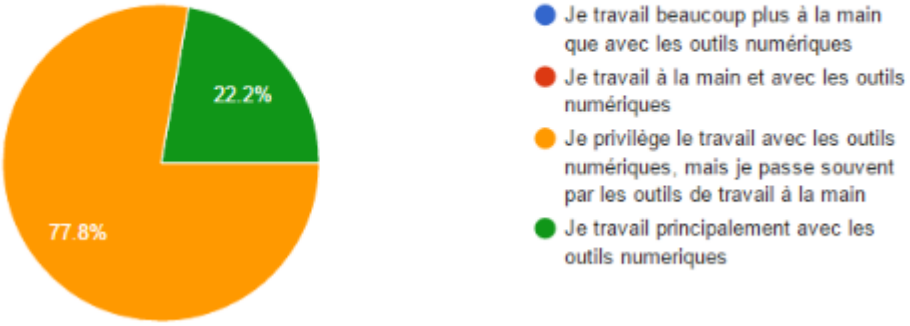
12.

Dans quels pays avez vous d'expérience? (12 responses)

France
France
France
France
France
France
Allemagne
Allemagne
Luxembourg
FRANCE
Espagne
france

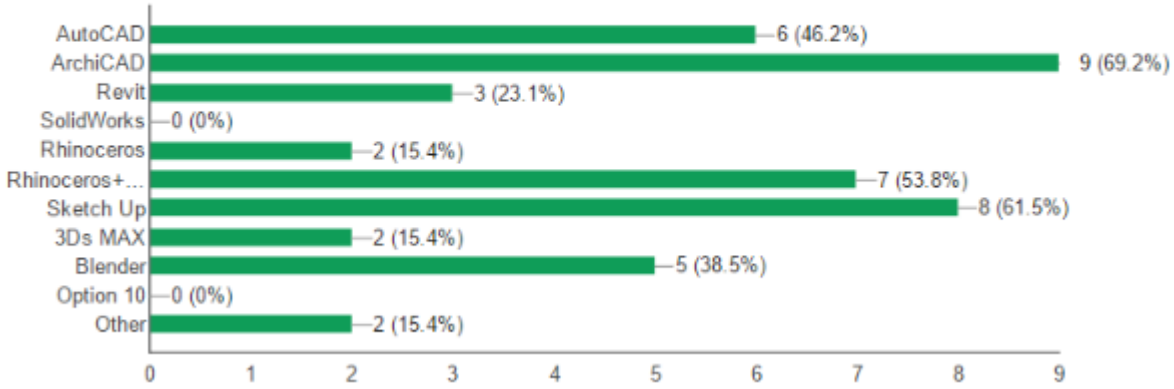
13.

Quel et le rôle des méthodes numériques dans vos pratiques? (9 responses)



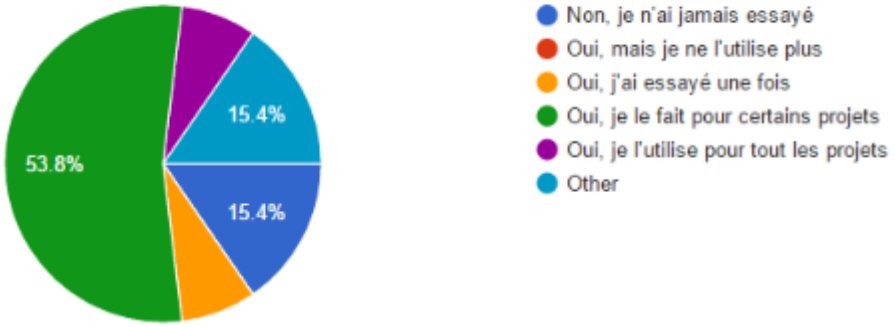
14.

Quels logiciels utilisez vous ? (13 responses)



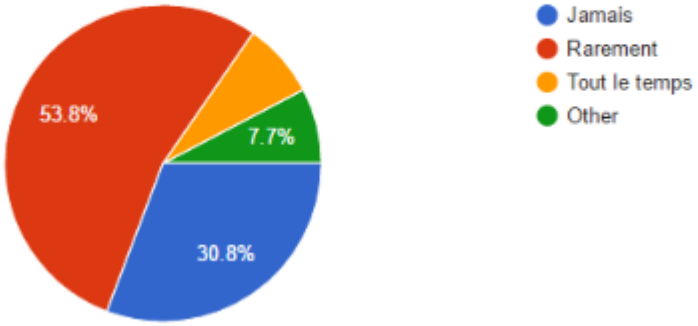
15.

Avez vous intégré des pratiques BIM dans votre travail ? (13 responses)



16.

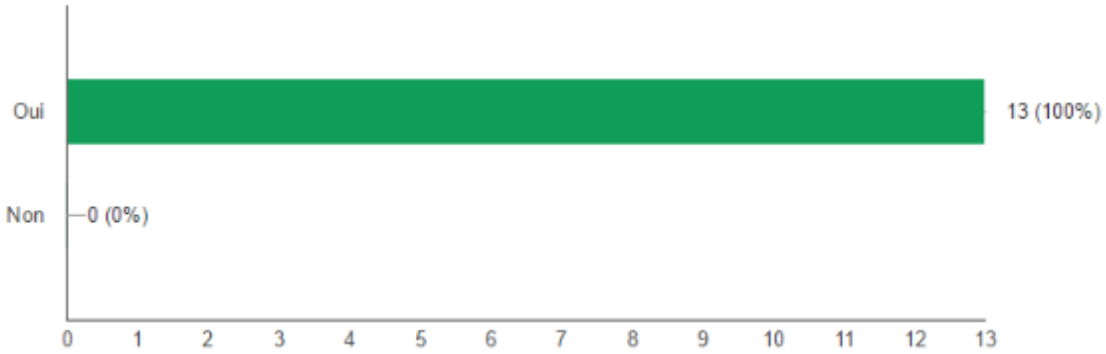
Pratiquez vous le travail synchrone à distance (Skype, Sketcha...) ?
(13 responses)



17.

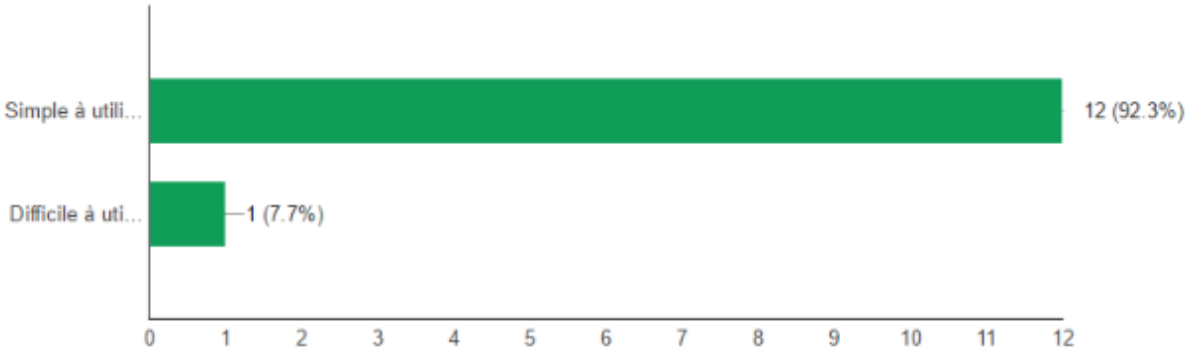
Résultats de l'expérience

Les objectifs de la session ont-ils été accomplis? (13 responses)



18.

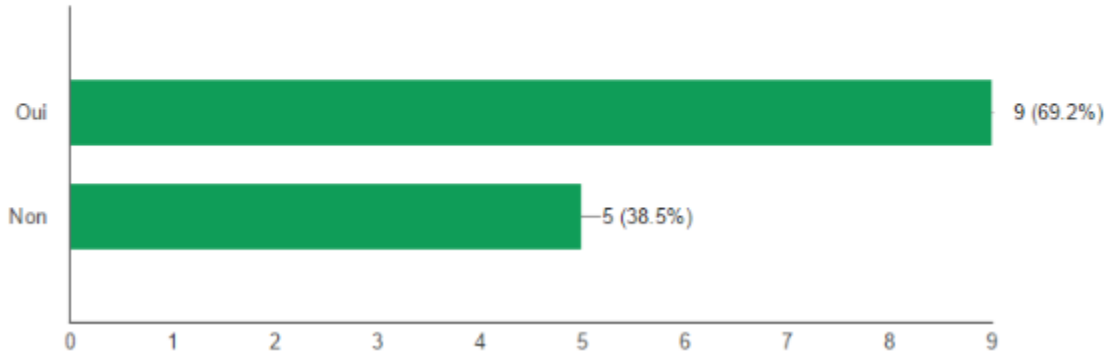
Quel est votre ressenti quand à l'équipement ? (13 responses)



19.

Est-ce que l'intérêt de la méthode vous semblait évidente avant l'expérimentation ?

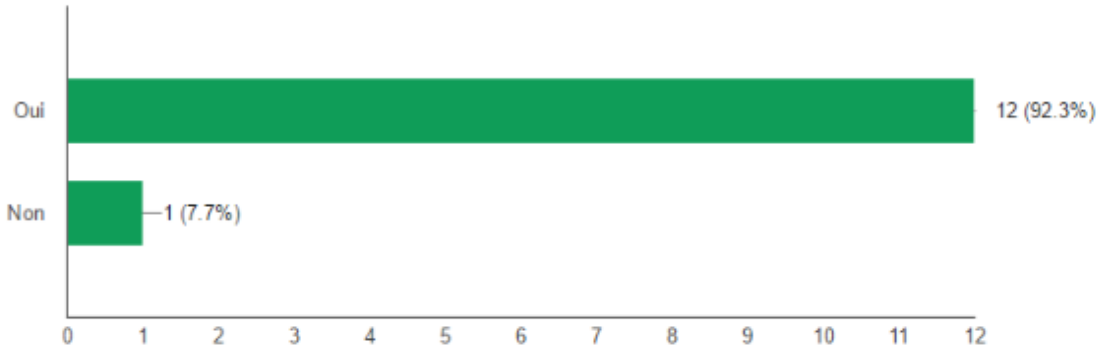
(13 responses)



20.

Est-ce que l'intérêt de la méthode vous semblait évidente après l'expérimentation ?

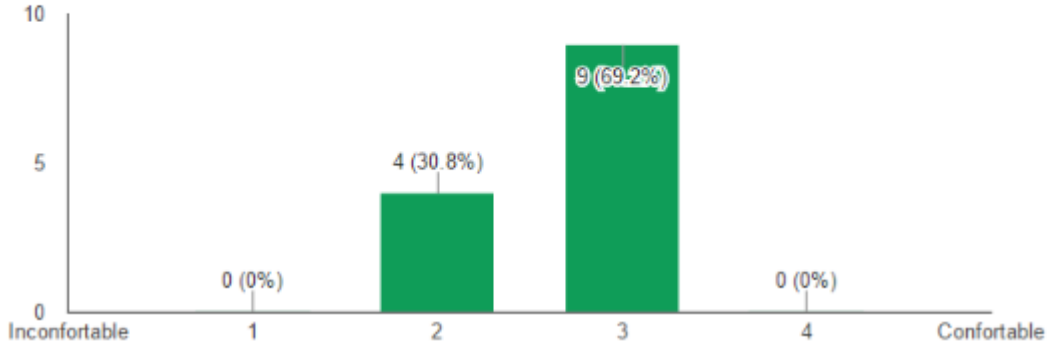
(13 responses)



21.

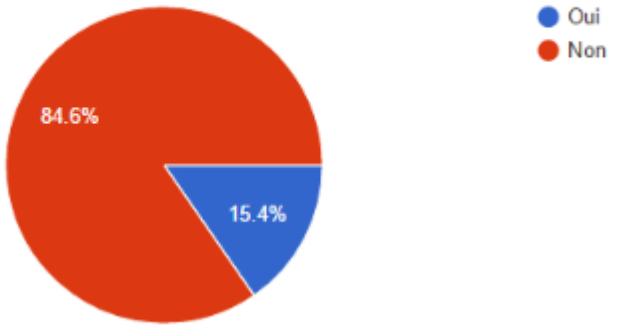
À quel niveau le matériel était-il confortable dans sa manipulation ?

(13 responses)



22.

Selon vous, cette méthode est-elle complète ? (13 responses)



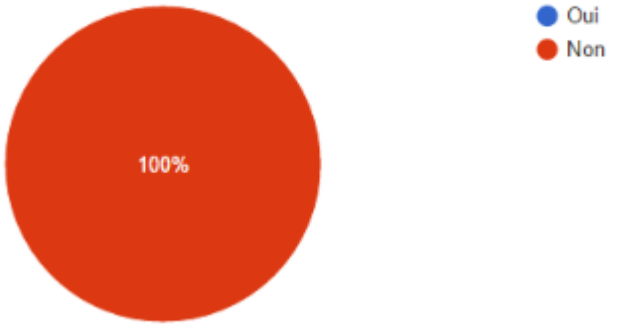
23.

Si non, que manque t'il le plus à cette méthode ? (11 responses)

Outils de dessin
de la souplesse dans la navigation 3D (cf Sketchup) ... edition "par calques" sur les plans / docs vectoriels
meilleure gestion des déplacements 3D ; accumulation de calques à la place des capture d'écran JPEG
Les couleurs coucou vero et le fait d'être sur le même réseau.
Navigateur à revoir, manipulation 3D
Travail à distance, ergonomie simplifiée
envoi de CR - Lecture de IFC - Conservation modif modifiables
Il s'agit uniquement d'annotation sur des documents, et pas d'un véritable travail en 3D
la possibilité d'enregistrer sous forme vidéo les séquences suivant ordre du jour avec voix pour faire office de compte-rendu de réunion de travail
une sauvegarde des annotations pour poursuivre le travail meme après avoir validé une premier notation
forcer la prise en main d'une fenêtre, pointillés sur le dessin, facilité d'import de documents

24.

Selon vous, cette méthode a-t-elle des outils superflus ? (13 responses)



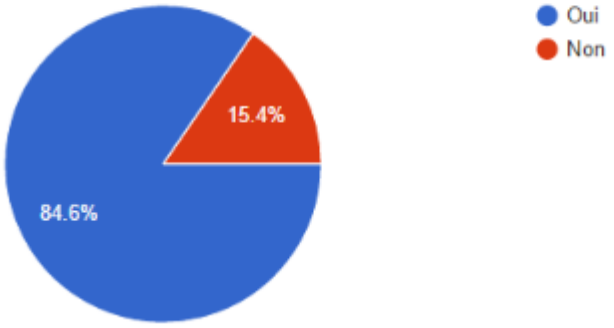
25.

Si oui lesquels ? (0 responses)

No responses yet for this question.

26.

Selon vous, un outil de travail collaboratif à distance est-il nécessaire à ajouter à cette méthode ?
(13 responses)



27.

Selon vous, en quelques mots, quels sont les avantage d'une telle méthode ?
(11 responses)

Visualisation
pratique pour modifier vite , corriger, discuter
Souplesse et interactivité "graphique"
bonne collaboration en cercle réduit
rapidité dans les décisions (pas besoin de se déplacer)
Concentration des données
Bureau virtuel relativement complet
Discussion facilitée et imagée
simplicité de prise en main, travail à plusieurs
C'est justement le fait de pouvoir travailler à distance à plusieurs. Le gain est énorme si l'ergonomie permet d'éviter aux personnes de se déplacer il suffit après de mettre le matériel à disposition dans les espaces de coworking accessibles en location
même vision du projet par le client (néophyte) et l'archi\l'ingénieur. Meilleure compréhension également de l'architecte vers l'ingénieur et vice versa

28.

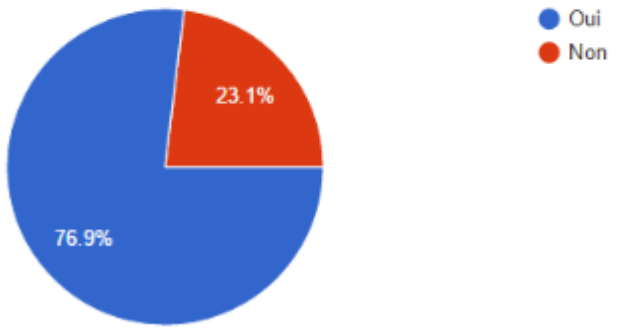
Selon vous quels sont les désavantages d'une telles méthode ? (11 responses)

Complexité d'assemblage des info
parfois on se concentre trop sur l'outil plus que sur le projet
quelques problèmes d'interface, navigation 3D laborieuse
logiciel incomplet
couteux
temps d'apprentissage, coût, amener les archis à s'en servir
Système fermé
Un peu anecdotique comme outils
Coût du matériel, lacunes (pas d'enregistrement vidéo de la session)
Résolution et ergonomie de la table. L'usage actuel de tablettes à la place me semble plus adapté et économique
Possibilité que le client fasse faire plus de modifications à l'architecte (impression de sa part de mieux maîtriser le projet)

29.

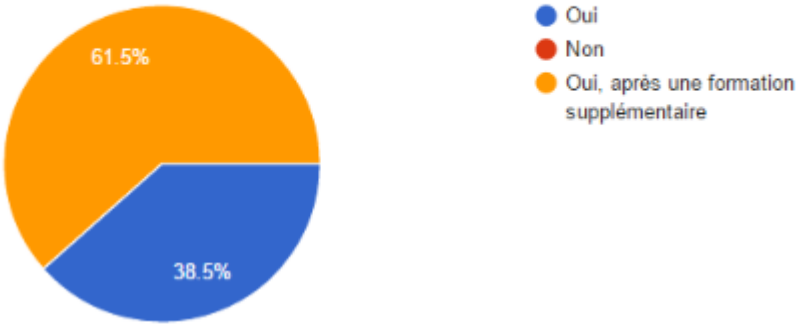
Perspectives

Seriez-vous intéressé de refaire une ou plusieurs expériences? (13 responses)



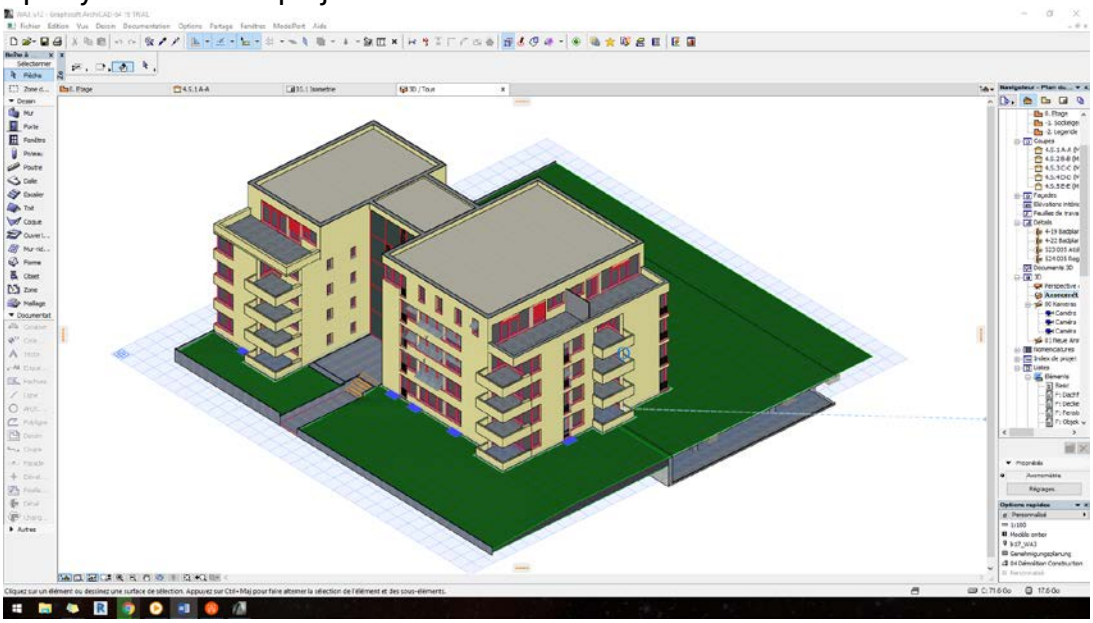
30.

Pensez-vous être apte à une utilisation autonome du système ? (13 responses)

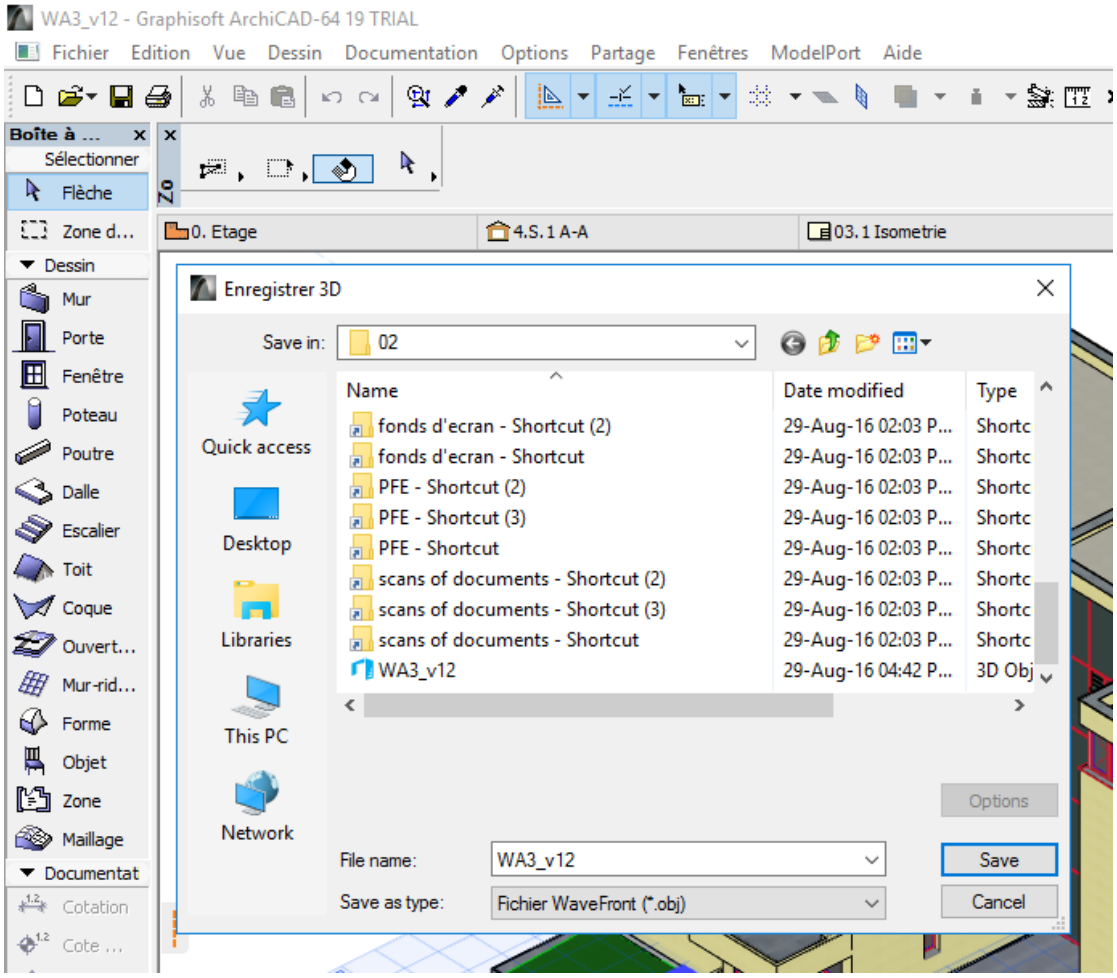


ANNEX II. GRAPHISOFT ARCHICAD 3D MODEL EXPORT TO .OBJ AND UPLOAD TO SHARIIING

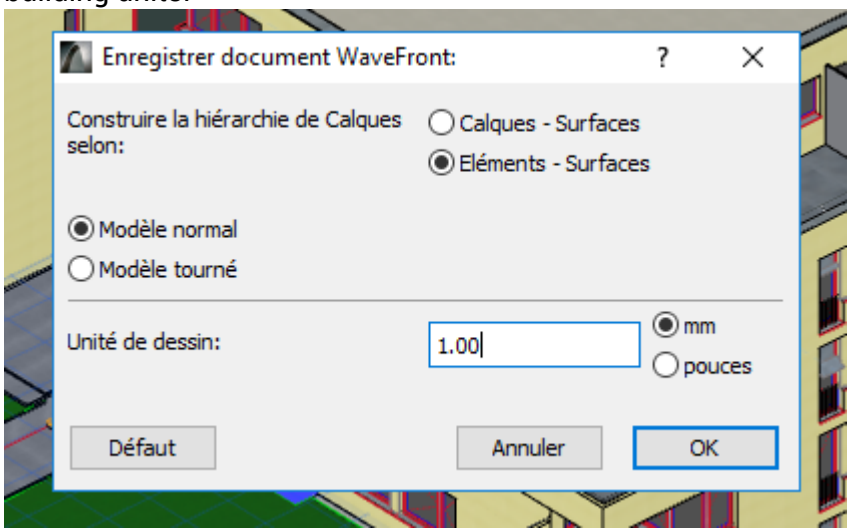
1. Open your ArchiCAD project in a 3d view.



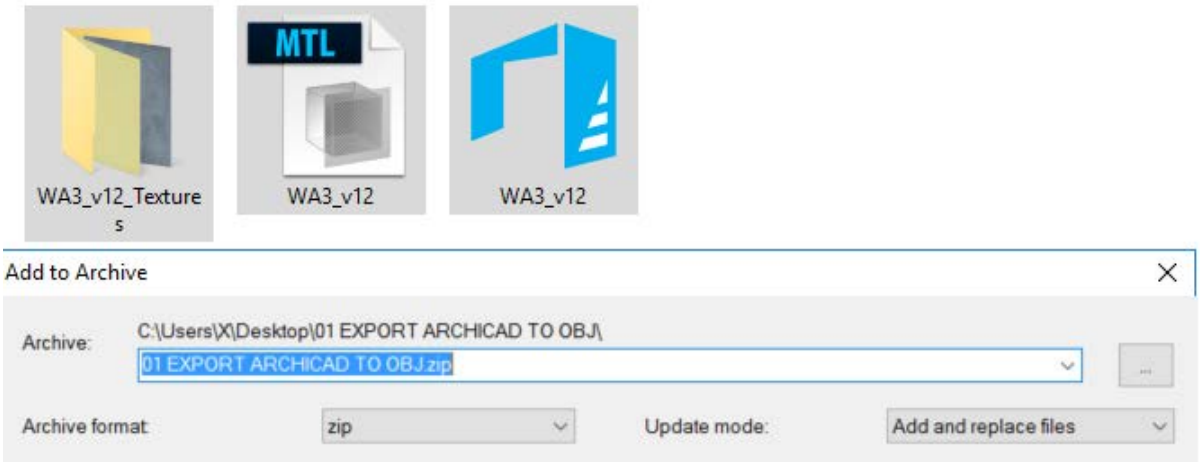
2. On a File menu select Save as… and choose the type WaveFront file (.obj), and press save.



3. On a saving settings window choose Normal model, and Elements-Surfaces, and the building units.



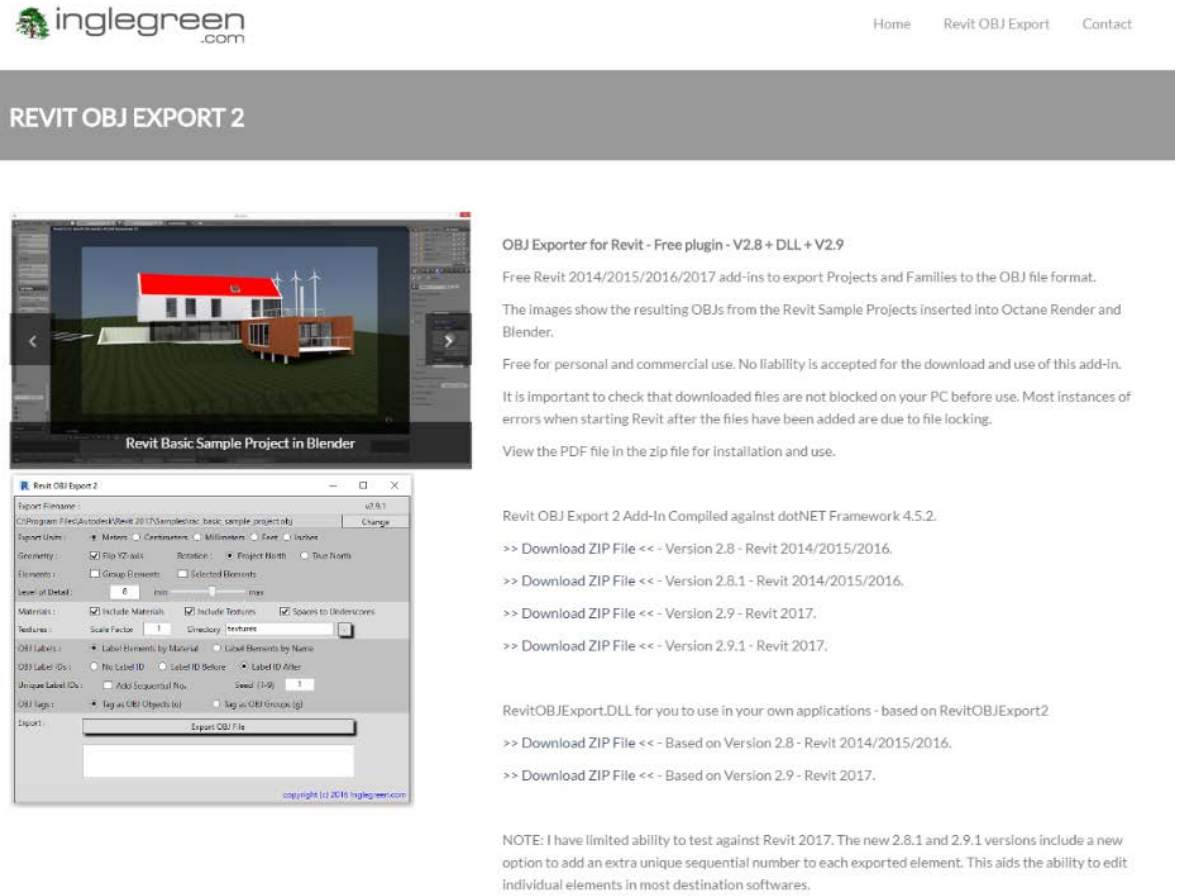
4. Your export will produce three types of information files: the 3D model in an .obj file, an .mtl file and a folder with texture files. Select the .obj, .mtl and the textures folder and add to a .zip archive.



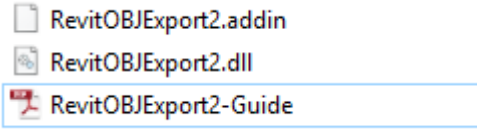
5. Upload the .zip file to Shariiing.

ANNEX III. AUTODESK REVIT 3D MODEL EXPORT TO .OBJ AND UPLOAD TO SHARIIING

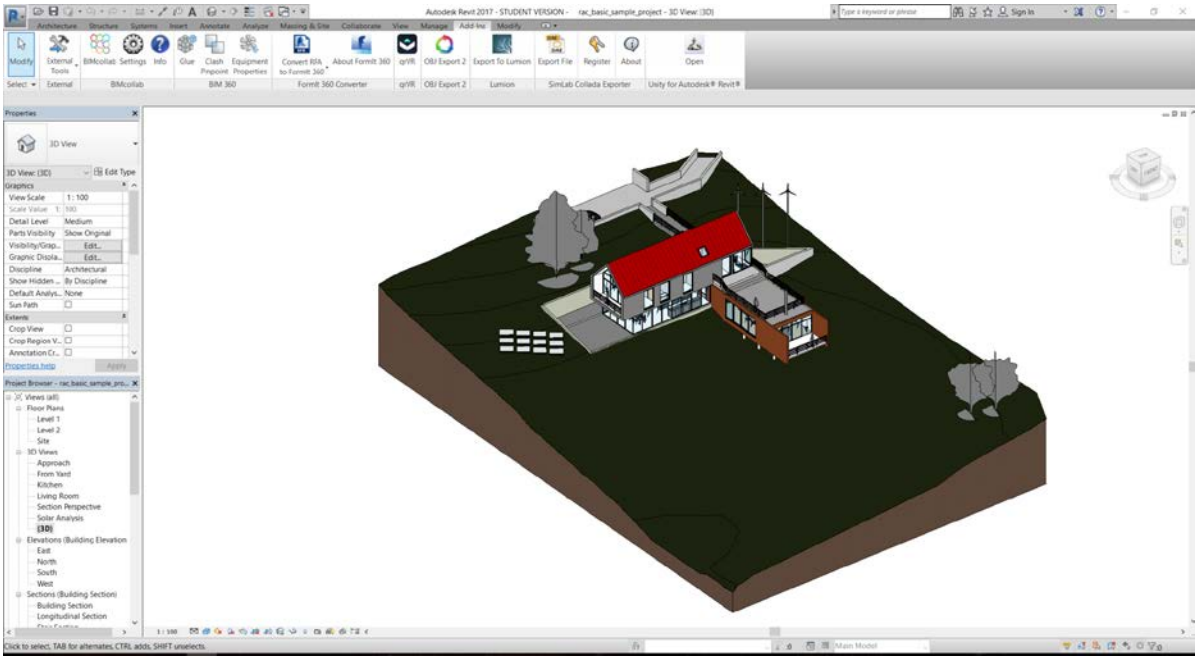
1. Revit basic savings settings don't support an .obj format export. So to be able to save your project file as an .obj you will have to install an add-ins. For example, "Revit OBJ export 2".(http://www.inglegreen.com/revit_app.html)Download the plugin version compatible with your Revit version.



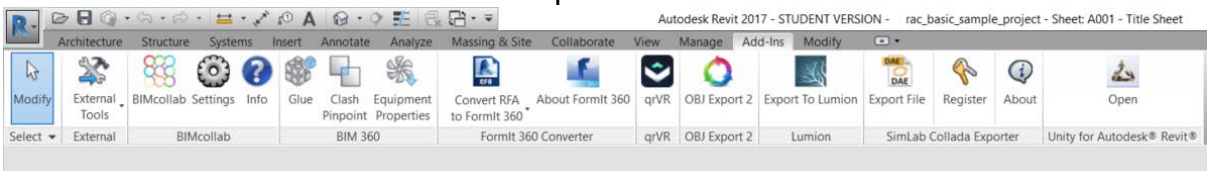
2. Follow the installation instructions for the plugin Revit OBJ export 2".



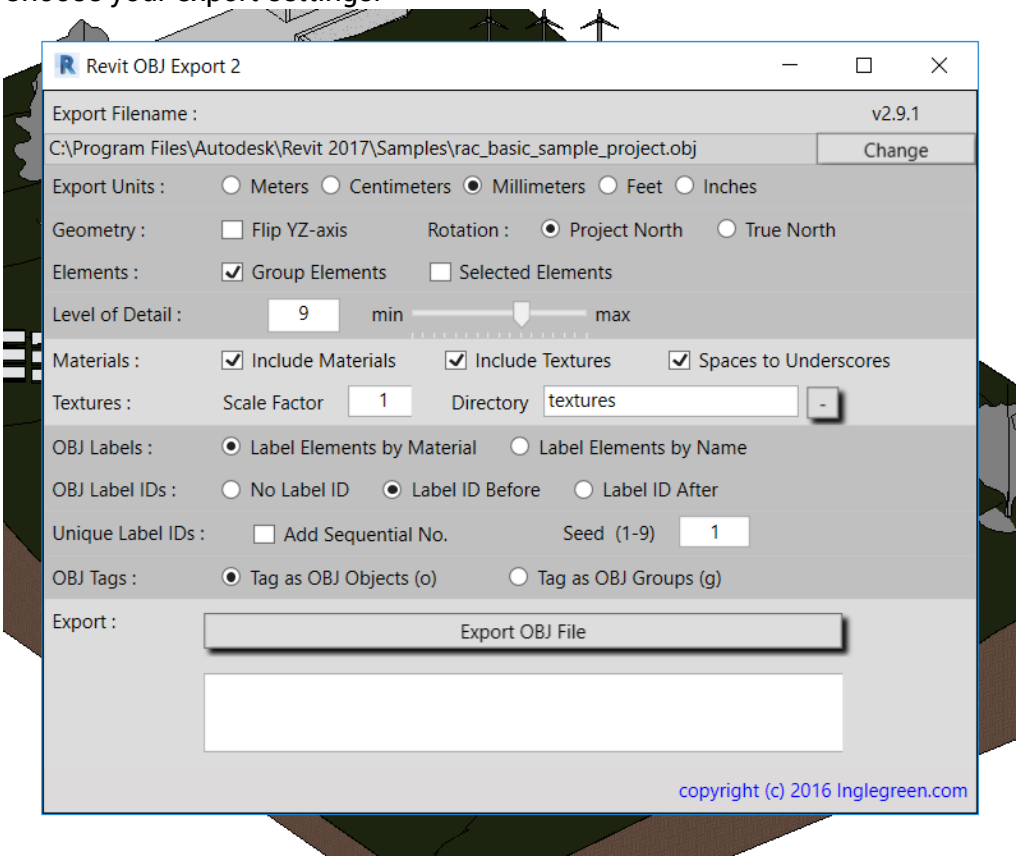
3. Open your Revit project.
4. Go to the 3D view of your project.



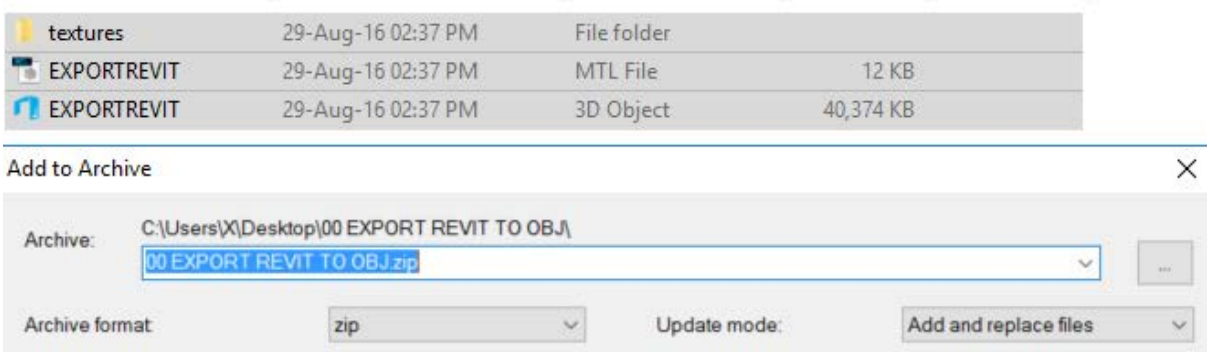
5. Find and select the “Revit OBJ export 2” in the Revit Add-Ins menu.



6. Choose your export settings.



7. Your export will produce three types of information files: the 3D model in an .obj file, an .mtl file and a folder with texture files. Select the .obj, .mtl and the textures folder and add to a .zip archive.



8. Upload the .zip file to Shariiing.

MÉMOIRE DE MASTER DESIGN GLOBAL SPÉCIALITÉ « ARCHITECTURE MODÉLISATION ENVIRONNEMENT »

SYNCHRONOUS COLLABORATION AND 3D INTERACTIONS AEC INDUSTRY IMPLEMENTATION

Veronika BOLSHAKOVA

2016