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cenários de colaboração e integração de projetos com BIM

scenarios for projects collaboration and integration by using BIM

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Abstract:

BIM (Building Information Modeling) currently stands out as an information technology focused on AEC (Architecture, Engineering and Construction), contributing to potentialize collaborative work and optimize design processes in architecture and engineering offices. In Brazil, despite the increase of researches on the subject, new studies that reflect on technology application experiences in still poorly exploited professional contexts are needed such as in the Northeast of Brazil and specifically in Natal, RN. For Souza et al. (2009), the evaluation and dissemination of BIM implementation experiences in architectural offices is relevant as it encourages new companies to use the technology. Therefore, the main purpose of this study is to characterize collaborative processes aiming at the integration of projects and to identify collaboration scenarios that result from the implementation of BIM in Natal architecture offices. The qualitative exploratory research is based on the analysis of case studies that address collaborative processes between architecture and engineering offices in Natal. In order to strengthen the study, reference studies were also carried out in national and international offices that use the BIM technology. Data collection was conducted mainly through semi-structured interviews and submitted to content analysis of the communications (Bardin, 2011). As a result, the analysis showed that Natal presents two scenarios[1] of collaboration using BIM.

Keywords: Architectural design. Collaborative processes. Integration of projects. Building Information Modeling (BIM).

1 Introduction

This study presents an analysis on the idea of work collaboration fostered by the BIM platform during the development process of architectural and engineering projects in Natal, RN. The notion of collaboration is combined with the integration of projects, an essential component of the discussion, since it refers to social issues as well as practical experiences of technological applications in yet poorly explored professional contexts such as in the Northeast of Brazil.

It is challenging to design using a platform that facilitates an interactive modeling process, considering that the understanding of how the platform tools work, specially by (non-academic) operators of different areas, is not completely established. On one hand, this study field demystify the role of digital technologies in contemporaneity. On the other hand, it supports the identification of growth potential of collaborative projects fostered by compatible software and articulated by an integrated thinking process, also revealing the demands for coherent and appropriate developing methods to the contexts in which these projects are used.

Among the digital technologies used for architectural design, Building Information Modeling (BIM) is increasingly prominent due to the benefits that it can bring not only to architecture offices but to the industry of Architecture, Engineering and Construction - AEC. Thus, computer-aided design (CAD) systems have been replaced by the BIM platform, even though slowly, in some contexts such as the national market.

One of the advantages of BIM in relation to other systems is its greater potential for collaborative work. According to Kowaltowski et al. (2011), BIM brings the idea of an integrated project practice from the earliest stages of the project and it offers resources that stimulate and facilitate collaborative work. Also, BIM fosters the integration of disciplines (architecture, structure, electrical and water and sanitary installations and special projects) from the beginning of the design process and not only at the end of it, aiming to generate a single virtual constructive model.

Despite of BIM's innumerous functions, Menezes (2011) considers that the platform, as it happened with CAD systems, became popular in Brazil with approximately 20 years of delay in relation to other countries. The software was initially used in the professional environment and then in the academic field. In recent days, "the market, even though having countless sources of information, is still showing a lack of knowledge on the subject" (Netto, 2015).

This panorama includes the Northeast of the country and more specifically Natal, where it was preliminarily verified that the knowledge and applications regarding the technology need to advance, both in academic and professional environments such as architecture and engineering offices. In addition, studies that address BIM application in architecture offices in Natal have not been identified.

Based on the aforementioned premises and considering study gaps and the necessity of researches on the use of a single constructive model in a local context, this research aims to characterize collaborative processes focused on the integration of projects. This study also aims to identify collaborative scenarios resulting from the BIM implementation in architecture offices in Natal as well as the importance of collaborative processes and integrated design practices with the assistance of the BIM platform.

According to Gehardt and Silveira (2009), this research is classified as qualitative and exploratory and it is based on multi-case studies such as collaborative design processes. These processes resulted from the collaboration between architecture and engineering offices that sought to integrate different disciplines (architecture, structures, water and sanitary installations, HVAC - heating, ventilation and air conditioning). Data collection in the architecture and engineering offices was mainly conducted through semi-structured interviews and project description followed by content analysis based on Bardin (2011).

2 Collaboration and BIM

The geometric model developed using BIM works not only as a building representation but also as a virtual construction with an associated database, which can be consulted and updated throughout the life cycle of the building - from design to construction, reform, retrofit and other interventions. Concerning BIM implementation in project offices, one relevant point to be observed is the team collaboration to project integration. For this purpose, the processes should be reviewed and the specialists (employees) need to adapt themselves to the new practices and digital tools of collaborative work. According to Manzione (2013),

> collaboration in AEC comprises complex workflows in which different agents need to be integrated in a common set of information over a long time period [...]. For the author, [...] during the design process, when BIM technology is used, **collaboration happens through the exchange or sharing of BIM models or their subsets** (Manzione, 2013, p.125, our highlights, our translation).

The construction market relies on several Information and Communication Technologies (ICTs), which aims to share and exchange BIM models. These technologies foster collaboration and communication between designers, resulting in different collaboration scenarios during data and model integrations. The exchanges and sharings "range from rudimentary mechanisms, such as the simple physical exchange of files, to sophisticated technologies of model servers" (Manzione, 2013, p.125, our translation).

According to Jørgensen et al. (2008), different collaborative scenarios for model development can be identified in a building construction project based on IFC[2] - Industry Foundation Classes. The authors outline three different scenarios (Separate Models, Separate Models with Aggregate Model and Shared Model), that are distinguished in relation to how much the project partners work together and how the modeling activities are coordinated.

According to Manzione (2013, p.3, our translation), "the study of collaborative work requires the consideration of four key resources: people, processes, technology and data".

There are several agents involved in collaborative processes associated with information model design such as consultants and designers of various specialties, construction professionals, landlords, developers, builders, construction components suppliers and manufacturers and construction team. The more complex the demands and the greater the enterprise size, the greater will be the employees’ network, the interaction between them and the need forpropercollaborative processes.

The increase of BIM use fostered the emergence of new positions, tools and functions as adaptations for collaborative practices and development of new teams and professional skills. Several tools were developed to assist the communication and collaboration of the agents involved in the development of projects.

Concerning the process of BIM collaborative design, there are several factors that can narrow the collaboration among agents and hamper the development of virtual construction. In general, these factors can be defined as limitations related to processes, agents or technologies such as fragmented and sequential processes, resistance to collaborative work and interoperability issues.

Kowaltowski et al. (2011, p.432, our translation) pointed out that "without efficient interoperability and effective collaboration, the idea of BIM as a work process is lost" [...] and that, "in practice, it observes that only few companies and professionals that use BIM tools seek interoperability and collaboration".

The condition of full collaboration is not easy to achieve as it is not a fast or automatic process. It requires time and cultural change. Hence, the necessity of reviewing the design process methodology, form of generation and information sharing is urgent to create the construction model and action, rules and responsibility limits for each professional involved in the process. The composition and interaction of the multidisciplinary team also need to be evaluated.

3 Methods, techniques and research instruments

This research was based on the analysis of six case studies in Natal and four reference studies - two in Brazil (São Paulo and Recife) and two in Argentina (Buenos Aires and Rosario). In this regard, this research is defined as **case study**, which consists of "[...] a deep and exhaustive study of one or more objectives, so as to allow its broad and detailed knowledge ..." (Gil, 2002, p.54, our translation).

The following items present a summary of the main steps, procedures and instruments used in the multi-case studies. In conformity with Gil (2002), the steps are listed below[3].

3.1 Formulation of the problem

This research sought to ensure that the problem to be analyzed could be verified from the study design.

3.2 Definition of the case unit

In this stage, the type of studied case and the selection criteria were defined. According to Stake's classification (2000 cited by Gil, 2002), the type of case studied is instrumental and it was developed with the purpose of assisting in the awareness or redefinition of a determined problem.

The studied case units consisted of collaborative processes that sought to integrate projects using BIM, among architecture and engineering professionals in Natal. The collaborative processes were mapped based on the descriptions of each office, considering the analyzed disciplines and focusing on architectural processes over the engineering ones. The main criteria used to define the case studies were:

a) Greater possibility of maximizing learning as proposed by Stake (1995);
b) The case unit should present, at least in one of the stages of architectural design process, collaborative work using BIM to integrate with at least one engineering discipline, regardless the BIM's implementation stage in the offices[4].

3.3 Determination of the number of cases

For Gil (2002, pp.139-140), there is no ideal number of cases, but it is common to use from four to ten cases. Thus, six studies were conducted in Natal seeking to understand the local reality and four reference studies seeking to expand and qualify the analyses and conclusions.

3.4 Protocol development

The interview protocol[5] composes the main data collection tool developed and applied in this study. Besides the office profile characterization, the interview topics covered three contextual units: a) **BIM Technology**: verification of aspects related to BIM implementation in the offices; b) **Architectural Design Process**: the mapping of architectural design process; c) **Collaborative Processes for Integrating Projects**: the comprehension of collaborative processes that integrate architecture and engineering disciplines.

3.5 Data collection

Data collection was mainly based on face-to-face and semi-structured interviews, which were recorded in audio and later transcribed, and complemented with information and images from previous developed projects. Data collection occurred between 2017 and 2018.

3.6 Evaluation and data analysis

After data collection, which occurred in conformity with Bardin (2011), the analysis was based on three fundamental phases: pre-analysis, investigation of material and processing of the results - inference and interpretation.

According to Manzione (2013), Ledo and Pereira (2004), ten categories of analysis were defined: design phases, tools (software), team, means of communication, product, worksets, tools of model sharing, coordination, interoperability, factors that limit collaboration and integration of projects.

3.7 Conclusions

The conclusions concerning the six case studies in Natal were presented after analyses.

4 Collaborative project processes using BIM

This section presents the analysis of the six case studies in Natal and four reference studies - two in Brazil (São Paulo and Recife) and 2 in Argentina (Buenos Aires and Rosario). A brief description of the reference and case studies and the profile of the participating companies[6] (Tables 1, 2, 3 and 4) is presented below.

Firms/ Companies/ Professionals	Field of work	Clients	Nature of the project	BIM implementation year
A	Architecture	Legal entity	Commercial and institutional	2014
B	Engineering	-	-	-
C	Architecture, Engineering, Construction	Legal entity	Houses, multi-family buildings, hospitals, airports, etc.	2012
D	Architecture	Legal entity	Houses, multi-family buildings, corporate buildings, factories, etc.	2002
E	Engineering	-	-	-
F	Architecture, engineering	Legal entity	Airports, railroad and highways.	2012

Table 1: Profile of the participating companies in the reference studies. Source: Personal collection, 2018.

Caption	Firms/Companies/ Professionals	Courses analyzed
ER 1	A + B	Architecture, HVAC.
ER 2	C (architect + engineers)	Architecture, Structures, Installations (water/sanitary, electrical, HVAC).
ER 3	D + E	Architecture, Structures, Installations (water/sanitary, electrical, HVAC).
ER 4	F (architect + engineers)	Architecture, structures, Installations (buildings), Earthwork, Urbanism, Landscaping e Infrastructure (drainage).

Table 2: Mapped national and international reference studies. Source: Personal collection, 2018.

Firms/ Companies/ Professionals	Field of work	Clients	Nature of the projects	BIM implementation year
G	Architecture, Construction	Legal entity and private individual	Single and multi-family (Vertical and horizontal condominiums)	2015
H	Engineering	Legal entity and private individual	Single and multi-family residencies, commercial (installations and structures)	2017
I	Architecture	Legal entity	Residential and commercial, firefighting installations	2014
J	Architecture, Engineering, Construction	Legal entity	Residential, commercial e institutional (factories, industries, malls, etc.)	2015
K	Architecture, Engineering	Legal entity	Infrastructure, institutional (airports, bridges, highways etc.)	2016
L	Engineering	Legal entity	Residential, commercial, institutional (supermarkets, convention center, etc.)	2017
M	Architecture	Legal entity and private individual	Residential, commercial, ambiance, installations	2011
N	Engineering	-	-	-
O	Architecture	Private individual	Residential, Commercial, Ambiance, Installations	2010
P	Architecture	Private individual	Residential, commercial, Ambiance	Not in use

Table 3: Profile of the participating companies in the case studies. Source: Personal collection, 2018.

Caption	Firms/Companies/ Professionals	Disciplines analyzed
EC 1	G + H	Architecture, Structures, Installations (water/sanitary, electrical)
EC 2	I + J	Architecture, Structures, Installations (water/sanitary, electrical)
EC 3	K + L	Architecture, Structures.
EC 4	M + N	Architecture, Structures.
EC 5	O (architect 1 + architect 2)	Architecture, Installations (water/sanitary).
EC 6	P + H	Architecture, Structures, Installations (water/sanitary, electrical, HVAC).

Table 4: Case studies mapped in Natal. Source: Personal collection, 2018.

The table below contains a summary of the analyzed multi-case studies.

Case	Description
Reference study 1 (Buenos Aires-AR)	Collaboration between architecture and engineering offices. Architectonic project divided in two main phases: draft and executive project. Commonly 4 to 5 architects are involved in the development of the shared proposal that is synchronized in central model and work set use. The collaboration starts after the conception of the draft. The integration of disciplines is performed by the architects using Revit.
Reference study 2 (Rosário-AR)	Collaboration between constructor and multidisciplinary team. The whole process is divided in six main phases: conception and cost analysis, draft, municipal phase, thick work, thin work and finishing. The professionals work in separate files (local files) synchronized to the central file accessible in a local network and each team is responsible for the progress of one discipline. The coordinator uses review tools to send comments and point out the incompatibilities. The software used in the integration of disciplines are Revit, Naviswork and Synchro.
Reference study 3 (São Paulo-SP)	Collaboration between office of architecture and engineering. The architectural design process has two main phases: basic design and executive design. With all the specialties defined, weekly meetings are held with the collaborators to integrate the projects, verify interference and define solutions and adjustments. Compatibility is performed in Navisworks.
Reference study 4 (Recife-PE)	Internal collaboration in architectural and engineering projects company. First, the architecture is defined in Revit. Then the project is shared on the local network through the central archive, with the engineers who define the structure and facilities. After defining building, earthwork, urbanism and landscaping, the files are incorporated in Navisworks for compatibility and detection of interference.
Case study 1 (Natal-RN)	Collaboration between architecture and construction company and engineering office. The design process begins with a volumetric study followed by the development of the floor plan, 3D model and detailing. After detailing, the BIM project is shared with the engineers, who make the structural and water and sanitary models and the interference detection of the disciplines in Navisworks
Case study 2 (Natal-RN)	Collaboration between architecture and engineering professionals. The collaborative work with the engineers occurred since the early stages of the development of the architectural solution. After the definition of the architectural project, the pre-dimensioning of the structure, the water/sanitary project and the electrical installations were carried out in Revit. The structure dimensioning is made using the Eberick program, and then the structural pre-scaling is updated in Revit. Interference detection is visually performed on Revit, without the use of any specific automated tools.
Case study 3 (Natal-RN)	Collaboration between architectural and engineering projects company and an engineering office. After modeling the basic architectural design in Revit, collaborative meeting takes place. The structure definition is performed in Eberick and exported in IFC. The integration of the disciplines is performed in Revit with no use of automatic tools for interference review and detection.
Case study 4 (Natal-RN)	Collaboration between architecture and engineering professionals. After defining the architecture, the architect meets with the engineer who will perform the dimensioning, considering the integration between the two disciplines. After a meeting between the two professionals, based on the consulting of the engineer, the architect makes, in another Revit file, the insertion of the structure, using a link with the architectural 3D file. Then, the insertion of the structure is made along with the visual detection of interference and the adjustments in the disciplines.
Case study 5 (Natal-RN)	Collaboration of the internal team of an architecture and engineering project office. The process begins with the preliminary study, followed by the architectural design. In this phase the installations are modeled from the link with the architecture file, when integrated solutions are defined. The installation and architectural proposals are made simultaneously and are finished with the adjustments. The architecture project still goes through the phases of legal and executive design. Interference detection is performed on Revit.
Case study 6 (Natal-RN)	Collaboration between architecture and engineering offices. The architectural design begins with the preliminary study followed by the preliminary design. The engineer's work is made during those phases, creating the structure using Robot and the installations also in the Revit. Interference detection is then performed in Navisworks. After compatibilization the architecture office develops the executive project.

Table 5: Summary table of reference and case studies. Source: Personal collection, 2018.

According to the aforementioned methodological procedures, the multi-case studies presented above were analyzed from determined categories that are described below:

4.1 Project phases

In the analyzed collaborative project processes, it verifies that most companies do not have flow charts or diagrams with clear definition of the project phases nor the level of development (LOD) of the models that should be achieved in each stage of the project. The offices presented a logical sequence of activities that seeks the development of proposals.

Among the analyzed companies, company C (RS 2) stands out in the control of the collaborative processes from the first phases – defining the activities to be carried out, LOD to be reached in each phase, tools used and professionals involved in the process. Company D (RS 3), pioneer in the use of BIM in Brazil since 2002, did not present clear definition of the phases during the process, for instance when the basic project ends and the executive begins - once data is conjoined for the building execution since the early phases. Nevertheless, this office also adopts determined phases for fee control and stages of project approval by the client.

In some reference and case studies, it observes that the first meeting between architecture and engineering collaborators occurred when the architectural proposal was already defined. The process was mainly sequential until the definition of the architectural design and henceforth the engineering disciplines began to be developed, following the traditional practice logic as presented in case study 1 flow chart (Fig. 1).

Considering the traditional practice concept, Kowaltowski et al. (2011) states that the integration occurs only after the architectural conception phase as well as topics related to engineering and cost. As a consequence, it verifies a limitation in the performance of the collaborators, since several decisions that could be made collectively were defined separately.

As it observes in RS 2, the project process carried out using BIM was the closest to the ideal, in other words, to what is described in theoretical references. It was noticed in RS 2 that office C sought to integrate the solutions between architecture and complementary disciplines since the earliest stages, anticipating collaboration moments to the beginning of the process (Fig. 2).

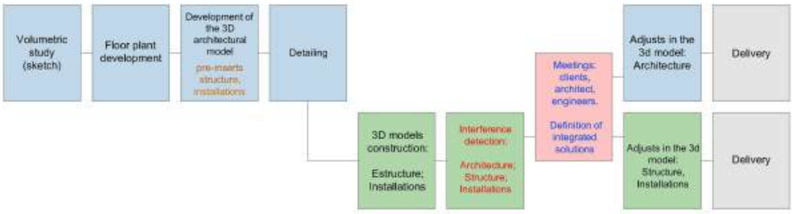

Fig. 1: Flowchart of case study 1. Source: Authors, 2018.

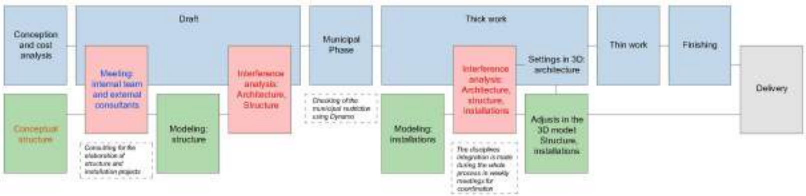

Fig. 2: Flowchart of case study 2. Source: Authors, 2018.

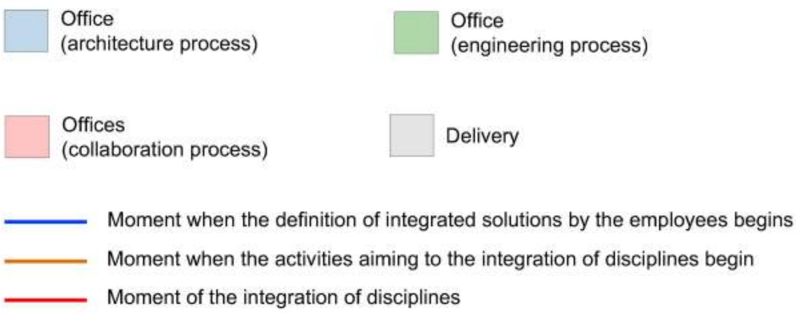

Fig. 3: Caption of figures 1 and 2. Source: Authors, 2018.

4.2 Tools (Software)

It observes that, excepting for company P (CS 6) that uses Sketchup and AutoCAD throughout the process to define the architectural proposal, all the other architectural design offices use the same BIM platform for architecture modeling.

The use of this tool by architects in RS 1, RS 2, RS 3, RS 4, CS 3 and CS 4 occurred since the earliest stages of the project, whereas in CS 1, CS 2 and CS 5 architects first drew the proposal by hand for volumetric definition and preliminary studies, then started to use BIM platform. After the volumetric study by hand, company G in CS 1 used CAD application for architectural floor plan definition and then BIM in project development. Although some of the surveyed offices still use CAD software, most of them have already transitioned to BIM.

In addition to using Revit and AutoCAD tools, the following softwares were also mentioned: Lumion, Photoshop and 3D Studio for graphical representation, Enscape for definition of finishing details, Ecotec for thermal simulations (Fig. 4), Ramsete for acoustics simulations and Dynamo – a visual programming software that allows to verify if the building is in accordance with municipal restrictions, based on the insertion of municipal data.

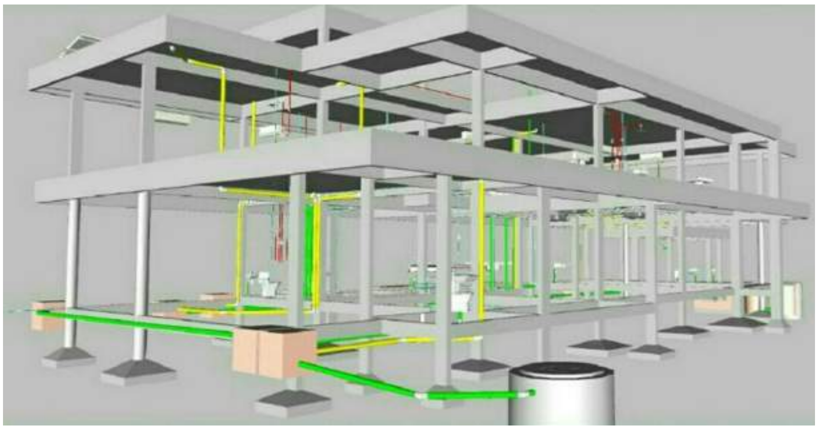

Fig. 4: Thermal simulation in residential building. Source: Company C, 2017.

As for the tools used to develop engineering projects, the most recurrent were Revit (for structural modeling and definition of water and sanitary, electrical and HVAC installations), Robot and Eberick (to structure definition). TQS was used by company N to compute concrete structures but the structural details were made in AutoCAD. Therefore, it can be noticed that engineering professionals are also in transition process from CAD programs to construction modeling software.

Navisworks is the most recurrent software directed to project coordination and it was applied in the processes CS 1, CS 6, CS 2, RS 3 and RS 4. In Natal, only H (engineering office) used this tool for compatibilization of disciplines as it optimizes the data integration. The integration of disciplines of high-standard residential designs can be observed in the following figures (Fig. 5 and 6).

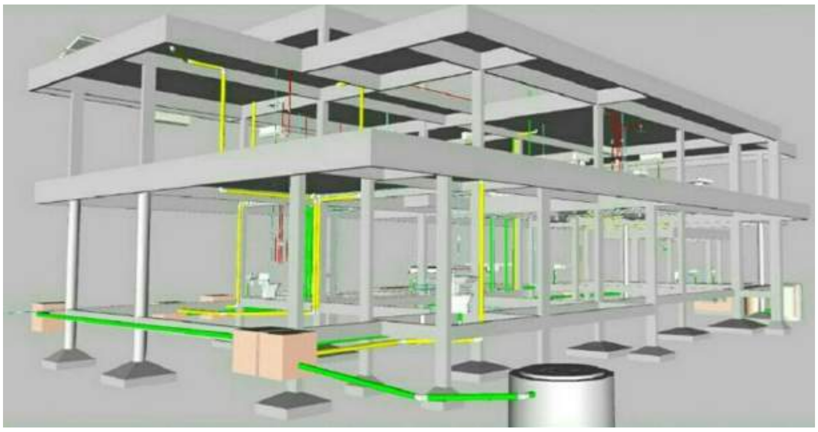

Fig. 5: Integration of disciplines in Navisworks - case study 6. Source: Company H, 2018.

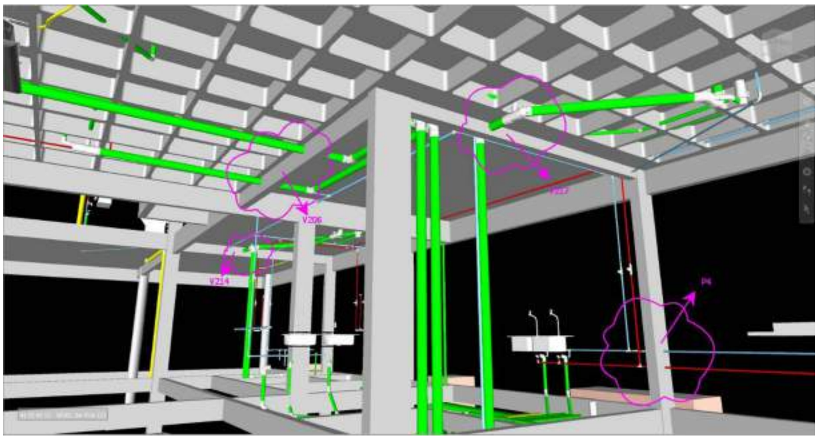

Fig. 6: Interference detection using Navisworks - case study 6. Source: Company H, 2018.

In the offices that do not use specific collaboration software, the integration of disciplines occurred in the modeling software itself, as seen in a corporate office building reform project developed by Company A (Fig. 7 and Fig. 8).

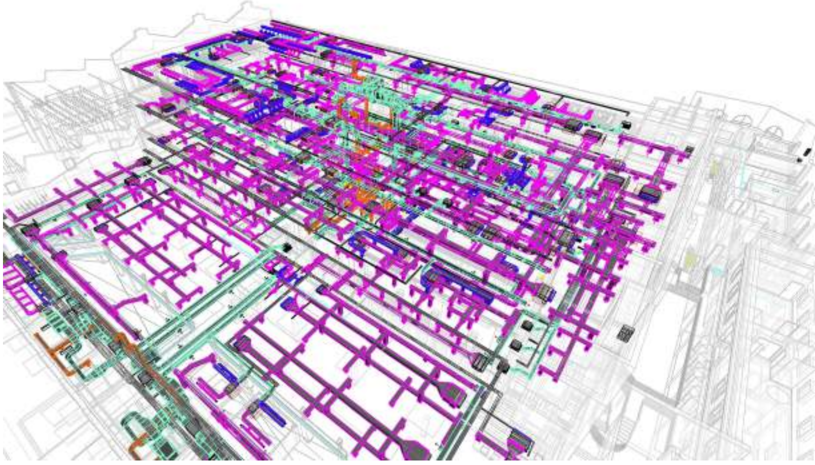

Fig. 7: Integration of disciplines in Revit - reference study 1. Source: Company A, 2018.

Fig. 8: Integration of disciplines in Revit - reference study 1. Source: Company A, 2018.

Despite the exceptions, it verifies that the resources of review, detection of interferences and communication to integrate the projects were underutilized by most offices. In some cases, communication through software was hampered by the poor quality of internet services and little knowledge on the potential of applications. Important collaboration tools were not mentioned such as BIM 360 Team, Teamwork, among others.

4.3 Worksets

In the architecture offices listed in the national and international reference studies, which presented larger projects and teams, it verifies that the possibility of simultaneous work by several architects, optimization of time processes and promotion of collaboration was fostered by using worksets.

In Fig. 9, it is possible to visualize in different colors various worksets created to compose an event space. While a designer worked on the "general proposal" (purple workset), others developed specific booth proposals (blue, green, and other worksets).

Fig.9: Collaborative work using worksets. Source: Company C, 2017.

4.4 Project team

According to Barison and Santos (2011), when investigating the BIM implementation scenario in the civil construction market in São Paulo, professionals from companies of small and medium sizes tend to accumulate activities and functions related to BIM. This reality was also found in most of the offices involved in this study. Commonly, both team members and, in particular, owners accumulate functions: project development and modeling, team coordination, process management and participation in the integration and compatibilization of disciplines. Some professionals also worked in technological researches aiming to improve processes and team qualification. Accumulation of roles and activities was also observed in companies with larger teams. Nevertheless, the distribution of tasks among professionals was encouraged. In these cases, it verifies an optimization trend in the BIM implementation.

4.5 Coordination

In the reviewed processes, a professional who deserves attention is the coordinator figure. In the case studies developed in Natal, coordinators, who usually are the owners of the architectural or engineering offices, possessed greater knowledge on BIM tools and the responsibility for integrating the disciplines relied on them. An exception was case study 6, in which the architecture office exercised greater control in coordinating the collaborative process – although AutoCAD is still used – but the integration of the disciplines was performed by the engineering office.

4.6 Means of communication

In all the analyzed processes, the collaboration between architects and engineers was fostered by face-to-face communication, meetings to adjust the proposals and compatibilization of disciplines. The use of emails, telephone and WhatsApp was also recurrent. Nevertheless, the communication between the professionals through the collaborative resources of BIM was mentioned only in one case.

4.7 Model sharing

The exchange of models and project information from various collaborators is an important aspect of the collaborative process between architects and engineers. Choosing the right way to share information speeds and optimizes collaborative processes.

In all the four discussed reference studies, it verifies the existence of internal teams that share the central file of a project through a local network. Local copies were created by the referred professionals and the modifications were synchronized with the central file, which was updated. Therefore, each specific discipline was developed by a designer at a time or several professionals worked together using worksets in different parts of the same discipline at the same time. As the projects and teams of these offices became larger, this sharing mode was best exploited.

In RS 2 and RS 4, the offices presented multidisciplinary internal staff with architects and engineers of different specialties sharing data through the local network. In contrast, architecture offices A and D in RS 1 and RS 3 were composed mostly of architects and the models were shared with external collaborators (engineers) using respectively Dropbox (cloud file sharing) and AutoDoc (online file storage service with restriction of downloads and uploads).

In the studies carried out in Natal, in particular CS 1, CS 2, CS 3 and CS 5, there is a predominance in the use of cloud storage services for file sharing between architecture and engineering collaborators. The analyzed cases emphasized that projects of different specialties were usually shared in separated and linked files.

Manzione (2013, p.127, our translation) classifies this form of sharing as a "physical files exchange of separated models". For the author, this is a rudimentary mechanism of model sharing with the transference of the physical file generated by the software uploaded, for example, in web repositories such as Dropbox.

Considering the web sharing, data exchange is asynchronous (in different times) and the control of downloads and uploads is necessary to avoid losses or information redundancy. Also, greater caution regarding security of information in the cloud and better management of versions and reviews of the projects are essential. In CS 3, a greater integration rework was observed when files were shared separately. For example, when the architect receives the engineering project and the architectonic project is more advanced and with new updates, the compatibilization of proposals is hampered.

4.8 Interoperability

Architects and engineers tend to use software from the same proprietary, in special Revit, Robot and Navisworks. This occurs due to the fact that those programs are provided by important software houses of CAD and BIM platforms, the lack of knowledge of professionals in relation to similar software from other proprietaries and most importantly to avoid interoperability problems between software from different providers.

4.9 Factors that limit collaboration and project integration

According to the interviewees, the factors that often limit collaboration and integration between projects are related to people. The necessity of training and the resistance to the adoption and using of BIM technologies is recurrent among professionals (Table 6).

Fields	Factors
Process	- Process of collaborative project not defined. Need for planning that fosters the collaboration.
People	- Not many architects in the Market develop projects using BIM. - Lack of interaction between professionals that are already in the market. - Clients do not pay more for projects developed using BIM - Contractor's lack of interest in collaborations for courses integration. - Demand of projects developed in AutoCAD for approval by public bodies. - Need for project teams training. - Resistance to implementation and use of new technologies.
Technology	- Interoperability problems. - Hardware and software limitations. - Need for better quality internet connection.

Table 6: Limiting factors for collaboration and integration of projects according to the interviewed professionals. Source: Personal collection, 2018.

The collaboration, integration of disciplines and lack of definition of collaborative processes by companies were also noticed. In most cases, the definition of activity flowcharts was not clear. This led to the underutilization of employees and ICTs and fragmentation of processes.

In addition, non-requirement of projects in BIM for approval by public agencies is another factor that hampers the adoption and collaboration with BIM, since it encourages professionals to continue to use CAD software.

4.10 Product

Concerning the integration of projects, a greater focus on compatibilization of geometric data and little attention were given to the insertion of the constructive parameters to be used throughout the life cycle of the building. This happens, among other causes, due to the form that contracts are made between clients and professionals. Such contracts are signed separately with each specialist. Thus, each office delivers its respective models and separate database.

5 Collaboration Scenarios

The analysis of all ten project processes addressed in this study stressed both similar and different aspects concerning the way the internal and/or external team professionals work together and the way such professionals develop the modeling and integrate the disciplines. Considering these three aspects and regardless of the particularities from each case, the analyzed processes were categorized into three collaboration scenarios.

In collaboration scenario 1, after the modeling of the architectural proposal, complementary projects were created from the first model. Based then on the link between the files, the interference check was performed. This step was not made automatically using clash detection features in specific revision tools but the modeling software itself by using visual observation by the professional responsible for the compatibility (coordinator)[7]. In this scenario, there was a greater possibility of data inconsistency and redundancy. The participating offices have reduced staff and the coordinators of the interference analysis also acted as designers (Fig. 10). CS 2, CS 3, CS 4 and CS 5 conducted in Natal were categorized in this scenario.

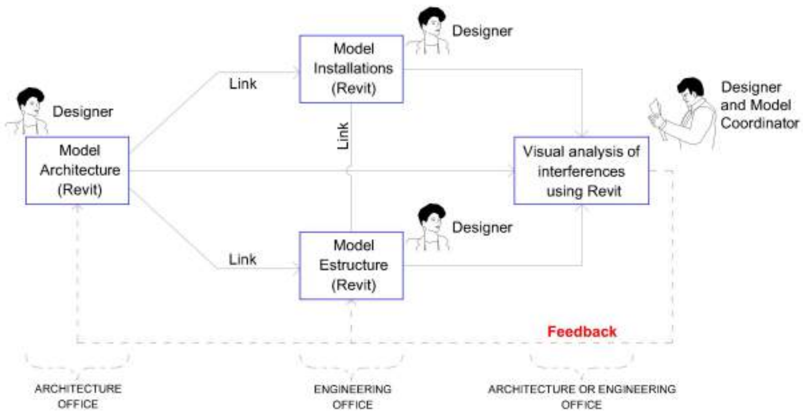

Fig. 10: Collaboration scenario 1. Source: Personal collection, 2018.

Scenario 2 presented similarities to scenario 1 concerning the professionals involved and modeling process based on the links between the files. Nevertheless, scenario 2 emphasized that integration moments were easily identified due to the use of a specific coordination and revision tool (Navisworks), which optimizes the reviews and contributes to reduce data inconsistencies (Fig. 11). CS 1 and CS 6 also conducted in Natal are examples of this scenario.

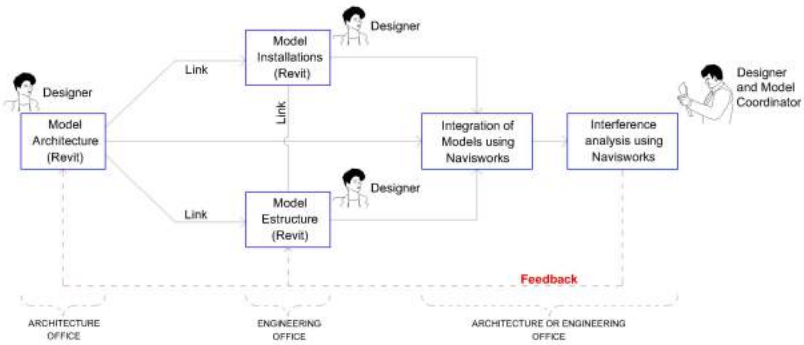

Fig. 11: Collaboration scenario 2. Source: Personal collection, 2018.

In scenario 3, it is noticeable the better use collaboration tools such as worksets and central model as the offices had larger teams and projects, allowing several designers to work at the same time on one or more models. Interference verification was performed with specific coordination and revision tools, promoting greater accuracy of the database (Fig. 12). The national and international RS 1[8], RS 2, RS 3 and RS 4 were categorized in this scenario.

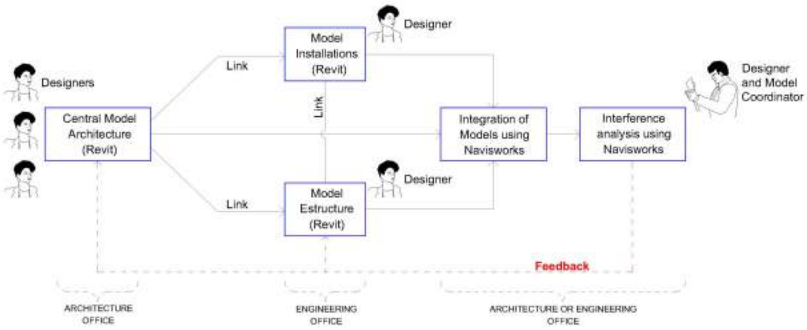

Fig. 12: Collaboration scenario 3. Source: Personal collection, 2018.

As identified in relation to the analyzed collaborative processes, the summary of the three collaboration scenarios is presented below (Table 7).

Scenarios	Modeling	Courses integration	Data	Interoperability
Scenario 1	Projects modeling based exclusively on links between files without central model sharing	Detection of interferences	Greater possibility for inconsistency and data redundancy	Lower
Scenario 2	Projects modeling based exclusively on links between files without central model sharing	Interference detection using specific review tool	Lower possibility of inconsistency and data redundancy	Lower
Scenario 3	Modeling of projects using links and sharing tools based on central model and local copies; Work and concurrent use of worksets	Interference detection using specific review tool	Lower possibility of inconsistency and data redundancy	Higher interoperability; Greater use of tool related to building efficiency.

Table 7: Summary of collaborative scenarios. Source: Personal collection, 2018.

Even though similarities were identified, the three analyzed scenarios differ from those proposed by Jørgensen et al. (2008), among other points, since the scenarios described by these authors refer to the collaboration using IFC. In contrast, few processes addressed in this study used IFC, since there is a predominance application of BIM modeling tools provided by the same manufacturer.

6 Final Considerations

This study fostered the analysis of how architecture and engineering offices from Natal and national and international contexts have performed collaboration to integrate projects using BIM platform. It was observed that in most of the mapped processes the integration of the disciplines, detection of interferences and model adjustments occurred only after the architectural modeling followed by the engineering process. Integration activities mainly aimed at making compatible the geometric data.

The advantages of using BIM were perceived as this platform enhances the collaborative design process. Even with exceptions, it was noted that the tools of collaboration and integration of disciplines are underutilized, both by Natal offices and other companies that participated in the reference studies. Compatibility and modeling software are generally provided by the same manufacturer. Thus, there is little interoperability using IFC extension standard.

The analyzed processes were identified and categorized into three collaboration scenarios, being two of them in Natal. A greater use of resources and collaboration tools was observed in scenario 3. This fact was also enhanced by the profiles of the teams and projects.

It was also noticed that offices with less technological resources but with greater control of the project process performed the collaboration and integration of disciplines more efficiently and developed projects with greater optimization degree. Most offices in Natal stated that there were no collaboration processes defined nor did specific software for communication, project review and integration of disciplines were used by them. Advances in knowledge, training and application of simulation tools related to sustainability, graphic programming and parameterization is also necessary.

Based on the analyses conducted in Natal, it is not possible to assume that the evaluated project processes presented full collaboration between architecture and engineering offices using BIM. Nevertheless, most frequent collaboration forms and project practices were identified.

At last, the research and analysis concerning the collaboration between architects and engineers in the contemporaneity involves the understanding of relevant factors such as team profiles, new social demands, design processes and the potentiality of application of Information and Communication Technologies (ICTs). The interaction between these factors increases the possibility of identifying different ways in which multidisciplinary designers can participate and collaborate in ACS, thus determining the emergence of collaborative scenarios and integration of projects as it is observed in this study.

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1 Previously to the case studies, a survey was conducted with architecture and engineering professionals that worked together using BIM. Another online study was carried out with architects registered at the Architecture and Urbanism Council of Rio Grande do Norte (CAU-RN). The gathered data contributed to promote the collaborative scenarios using BIM in Natal, considering a multi-case analysis. In this research, the term scenario is used to categorize forms and levels of collaboration and integration of disciplines identified in Natal.

2 In order to enable interoperability between different BIM software and ensure the maintenance and exchange of relevant data, the Industry Foundation Classes (IFC), developed by buildingSMART, has been adopted as a file format.

3 In this research, the sequence of steps proposed by Gil (2002, p.137) was adapted.

4 Concerning this criterion, the considered participants were: i. Architecture and engineering offices (internal collaboration); ii. Architecture or engineering offices (internal collaboration) that developed at least one discipline and shared project(s) with partner(s) (external collaboration); iii. Offices acting in project development and not only 3D modeling; iv. Indication of the offices by authorized BIM software representatives and BIM instructors with certification; v. Location of the office in the addressed geographical context; vi. Offices that could respond to the interview protocol and present projects that exemplify the described process.

5 The elaborated protocol can be consulted in Martins Júnior (2018, p. 89).

6 Concerning the sixteen listed companies, it was not possible to interview the engineering offices B, E and N. The processes that these offices attended were mapped based on information from the architecture offices with whom they collaborated. Most are small-sized offices, except for A, C, D, F, and K, which are medium-sized. According to Barison and Santos (2011), small companies have one to ten employees, medium-sized companies between 11 and 100, and large companies with more than 100 employees.

7 Integration of disciplines and detection of interferences are usually carried out by the architecture or engineering office that participates in the collaborative process. Such professionals have greater ability to use the coordination and revision tools of projects.

8 In RS 1, the integration of disciplines and interference detection were carried out by the architecture office using the modeling software itself and not a specific software of project coordination. RS 1 was categorized in scenario 3 based on the architectural design modeling process, which file sharing was based on the central model and editing of local copies, considering the use of worksets. This was the form of modeling and sharing the architecture project verified in the other analyzed reference studies. The modeling method was the first criterion adopted to define the collaboration scenario of each case study.