http://periodicos.sbu.unicamp.br/ojs/index.php/parc
http://dx.doi.org/10.20396/parc.v7i2.8646358

BIM BASED REQUEST FOR INFORMATION CLASSIFICATION AND DISTRIBUTION: TWO RESIDENTIAL TOWER CASES

CLASSIFICAÇÃO E DISTRIBUIÇÃO DE REQUISIÇÕES DE INFORMAÇÃO BASEADAS EM BIM: DOIS ESTUDOS DE CASO DE TORRES RESIDENCIAIS

João Bosco Pinheiro Dantas Filho[1]
Instituto Federal de Educação, Ciência e Tecnologia do Ceará, Fortaleza, CE, Brasil, joaobosco@ifce.edu.br

Bruno Maciel Angelim[2]
FortBIM Engenharia, Fortaleza, CE, Brasil, bruno@fortbim.com.br

Joana Pimentel Guedes[3]
Universidade Federal do Ceará, Fortaleza, CE, Brasil, joanapguedes@gmail.com

José de Paula Barros Neto [4]
Universidade Federal do Ceará, Fortaleza, CE, Brasil, barrosneto@gercon.ufc.br

Abstract

Request For Information (RFI) is a communication tool to facilitate resolution of, or to clarify, construction issues. Traditionally, construction teams generate RFIs, but with BIM they are anticipated being generated before construction by designers. The aim of this study to improve the understanding of how design conflicts happen through the lenses of RFI and motivate a proactive design review approach. The study was developed as a case study of RFI distribution and classification in the design of residential towers using a Virtual Design and Construction (VDC) approach. Semi-structured interviews were conducted with the virtual construction team coordinator. The interviews were transcribed and transformed in process map, especially, explicating how Request For Information was generated and how the interaction among the participants occurs. A documental analysis was performed on coordination models characterizing the type of RFI, its location, and quantity distribution within design discipline. The design process map drawn shows a partially implemented VDC where design developed with traditional CAD tools benefits from a design review process developed with virtual prototyping and 3D coordination with BIM tools. The distribution patterns of RFI quantities denote where the greatest effort in the review was, exposing design complexity. The analysis here presented may be applied to new situations other than those studied in order to promote learning within and metrics for VDC.

Keywords: Virtual Design and Construction. VDC. Request For Information. RFI. Building Information Modeling. BIM. 3D coordination. Virtual Prototyping.

Resumo

Requisição de Informação (RFI) é uma ferramenta de comunicação para facilitar a resolução de, ou para esclarecer, questões de execução da construção. Tradicionalmente, as equipes de construção geram RFIs, mas com o BIM estas são antecipadas sendo geradas antes da construção pelos projetistas. O objetivo deste estudo é melhorar a compreensão de como os conflitos de projeto acontecem através da lente das Requisições de Informação e motivar uma abordagem de revisão proativa do projeto. O estudo foi desenvolvido como um estudo de caso caracterizando a distribuição e classificação de RFI no projeto de torres residenciais usando a abordagem de Projeto e Construção Virtual (VDC). Foram realizadas entrevistas semiestruturadas com o coordenador da equipe de construção virtual. As entrevistas foram transcritas e transformadas em mapa de processo, especialmente, explicitando como a Requisição de Informação foi gerada e como ocorre a interação entre os participantes. A análise documental foi realizada em modelos de coordenação caracterizando o tipo de RFI, sua localização e distribuição quantitativa entre disciplinas de projeto. O mapa de processo de projeto desenhado mostra um VDC parcialmente implementado onde o projeto é tradicionalmente desenvolvido com ferramentas CAD e se beneficia de um processo de revisão de projeto em BIM com o desenvolvimento de protótipos virtuais e a coordenação 3D. Os padrões de distribuição de quantidades de RFI denotam onde ocorreu o maior esforço de revisão, expondo a complexidade do projeto. A análise aqui apresentada pode ser aplicada a novas situações que não as estudadas, a fim de promover aprendizagem entre projetos com o VDC e métricas para VDC.

***Palavras-chave**: Projeto e Construção Virtual. Requisições de informação. Modelagem da Informação da Construção. BIM. Coordenação de projetos. Coordenação 3D. Prototipagem virtual.*

How to cite this article:

DANTAS FILHO, João Bosco Pinheiro et al. BIM based requests for information classification and distribution: two residential tower cases. **PARC Research in Architecture and Building Construction**, Campinas, SP, v. 7, n. 2, p. 75-88, june 2016. ISSN 1980-6809. Available at: <http://periodicos.sbu.unicamp.br/ojs/index.php/parc/article/view/8646358>. Date accessed: 30 jun. 2016. doi:http://dx.doi.org/10.20396/parc.v7i2.8646358..

Received in 15.08.2016 - accepted in 07.11.2016

Introduction

Much research, in Building Information Modeling (BIM), is in progress in Brazil related to: design authoring (ANTUNES; SCHEER, 2014; DEBS; FERREIRA, 2014; DEZAN, 2014; MORORÓ et al., 2016), construction system design (MONTEIRO; FERREIRA; SANTOS, 2009; ROMCY et al., 2014; NEIVA NETO; RUSCHEL, 2015); 3D control and planning (BIOTTO; FORMOSO; ISATTO, 2015; BRITO; ANDRADE; FERREIRA, 2015) and existing condition modeling (DEZEN-KEMPTER et al., 2015). However, little has been studied on tools for design coordination and error mitigation.

Design errors are a problematic issue to the Architecture, Engineering and Construction (AEC) industry, and they can be avoided through the adoption of design managing actions (LOPEZ et al., 2010). In this context, the design coordination has, as its main expectation, the reduction of execution failures due to errors or inconsistencies in design. BIM can help AEC industry to find potential problems before construction starts (SACKS; BARAK, 2006). Zuppa, Issa and Suermann (2009) identified that BIM is frequently perceived of as a tool for visualizing, coordinating, and improving AEC work and productivity. Construction organizations need to openly acknowledge errors presence so that "learning from errors" can form an integral part of an organization's fabric (LOVE; SMITH, 2016).

Request For Information (RFI) is a communication tool to facilitate resolution of or to clarify design issues. RFIs can indicate design errors and initiate improving opportunities prior to construction. The cost per RFI may overcome US$ 1,000.00 each, based exclusively on the technical and administrative reviewing associated cost (HUGHES et al., 2013). Lopez et al. (2010), developed a study in order to understand how and why RFIs happen and which strategies can be thought to solve them. According to Lopez et al. (2010), the design error classification offers the bases to considerate the strategy adjustment to avoid and minimize errors.

Therefore, the aim of this study is to evaluate qualitatively the Request For Information in order to improve the understanding of how design conflicts happen and motivate a proactive identification approach. The study was developed as a case study of RFI distribution and classification in the design of residential towers using a Virtual Design and Construction-(VDC) approach.

Virtual Design and Construction (VDC) and Building Information Modeling (BIM)

BIM is understood as a set of policies, processes and technologies to promote a methodology to manage the design data and the construction design data, essential to the digital format in the whole building cycle (PENTTILÄ, 2006; SUCCAR, 2009).

According to Chua and Yeoh (2015), BIM provides the technology to share information and promote collaboration across organization and phases. BIM has gained increasing acceptance in the AEC industry. However, its adoption must be accompanied by transformation in processes. VDC represents this transformation.

VDC was first coined by Kam and Fischer (2004). Chua and Yeoh (2015) describe VDC "*as a concept or approach to build, visualize, analyze, and evaluate project performance virtually and early before a large expenditure of time and resources is made*". VDC is adopted in this study through this perspective.

Studies point how wide the BIM service delivery range is, such as, design coordination, clash detection and construction work sequencing (AZHAR et al., 2008). Clash detection using a BIM 3D coordination tools is able to identify several conflicts that may go unnoticed by professionals who perform their task manually. On the other hand, manual clash detection identifies conflicts that could not be found through software in cases were clashing objects are not modeled in the BIM (LEITE; AKINCI; GARRETT, 2009). Results show that the combination of clashes identified automatically, as well as those identified in the field captures the largest possible number of clashes. 3D coordination tools require virtual prototyping, that is, BIM models.

BIM models from all disciplines can be brought together and compared, and with this, conflicts and constructability[1] problems are identified before they are detected in the field (EASTMAN et al., 2011).

Request For Information (RFI)

It is while the work takes place that several unpredicted design questions come up and, in general, Request For Information "*are created by subcontractors and transmitted to the general contractor, and then to the design team for comprehensive review*" (CHIN, 2009, p. 258).

Traditionally, construction teams generate RFIs, but with BIM the Requests For Information are anticipated being generated before construction by designers. NATH et al. (2015) suggested that the RFI submission and approval process may be improved by using BIM Collaboration Format (BCF), which permits the users to share the encoded messages among different BIM platforms about the issues identified in the BIM model. Therefore, reduction of the RFI numbers in the construction site, do to prior treatment, is an example that highlights the aggregated value of BIM use (LEITE et al., 2011).

Despite meaningful capacities of BIM tools, modeling and interoperability deficiencies remain without solution. Thus, it is important that BIM companies keep improving the modeling and interoperability options to facilitate the interdisciplinary collaboration in the creation, review, update and reuse of 3D model information (ARAM; EASTMAN; SACKS, 2013).

Information Delivery Manual (IDM)

Researches point the main source of wasted information is inadequate information exchange and it is necessary to fully understand the interactive nature of the process of design (AL HATTAB; HAMZEH, 2013). Current design coordination strategies neglect the role of appropriate information flow and the communication among the design participants (AL HATTAB; HAMZEH, 2015).

According to BuildingSMART (2010), the establishment of an Information Delivery Manual (IDM) aims to provide a reference embracing the Request For Information for AEC industry, identifying the processes that demand the exchange or sharing of information among the design participants.

By following the patterns of IDM methodology, maps of processes and exchange models can be created. Antunes and Scheer (2014) demonstrated how to identify which information was necessary for the execution of a structural design with IDM methodology.

Design Coordination

In building construction, the process of design coordination is more often carried out by comparing or matching technical drawings of different disciplines in a design coordination meeting (RILEY; HORMAN, 2001). Bellan and Fabricio (2010) analyzed managing actions, coordination procedures and tools, and observed that the professionals must realize great effort of abstraction to align the two-dimension technical drawings to understand and preview the 3D work reality.

Case studies showed a transition moment between a conventional process and the new process of BIM coordination, which reveals itself as a very efficient means for a design team, as well as for coordinators and contractors (FARINA; COELHO, 2015).

According to Tommelein and Gholami (2012), BIM coordination is a process of integration of interdisciplinary models involving interferences checking in order to detect and solve conflicts, mitigating future likely problem.

Although BIM is considered helpful in improving design quality by eliminating conflicts and reducing rework, BIM also has to be applied throughout the project for construction quality control and efficient information utilization (CHEN; LUO, 2014). In consensus, Leite; Akinci and Garrett, (2009) observed that, in a case study of mechanical, electrical and plumbing (MEP) design coordination, the combination of manually identified design conflicts in coordination meetings, with those automatically detected, as well as with those identified in the field, allowed the highest performance of the coordination process.

A research-action developed in a building company showed BIM clash detection carried in the construction phase, after the design phase, allowed to check architecture designs, structure and building systems and the sharing of all conflict information so the designers could adjust their 2D designs (NEIVA NETO; FARIA; BIZELLO, 2014). However, the construction model development required a robust BIM construction system component library, to be used by different parties involved in the whole construction cycle. These BIM components should be developed taking into account requirements for different BIM uses from modeling to cost estimation, 3D control and planning (NEIVA NETO; RUSCHEL, 2015).

Considering code checking as a tool to improve design quality in design coordination, Kehl e Isatto (2015), observe that the geometric precision of the model and the associated information influence the feasibility of its application. Besides, not all the rules are automatically verifiable or are worth the effort to become so, especially the qualitative ones, being necessary the manual verification (KEHL; ISATTO, 2015).

Method

This study is exploratory and descriptive. The research question is “How are Request For Information distributed referring to residential design?” To answer the research question, it was chosen the Case Study strategy, as outlined by Yin (2001), therefore the results are qualitative.

Figure 1 shows the research outline, which comprises five steps. Initially, a bibliographic review was carried out in the study theme. Then, the study delimitation and the elaboration of the protocol for data collection and analysis took place. Data were collected from documental analysis and interviews. Data analysis developed upon design process map observed and classification of RFIs Finally, the report is resumed in this article.

Figure 1 – Research design

Source: The authors

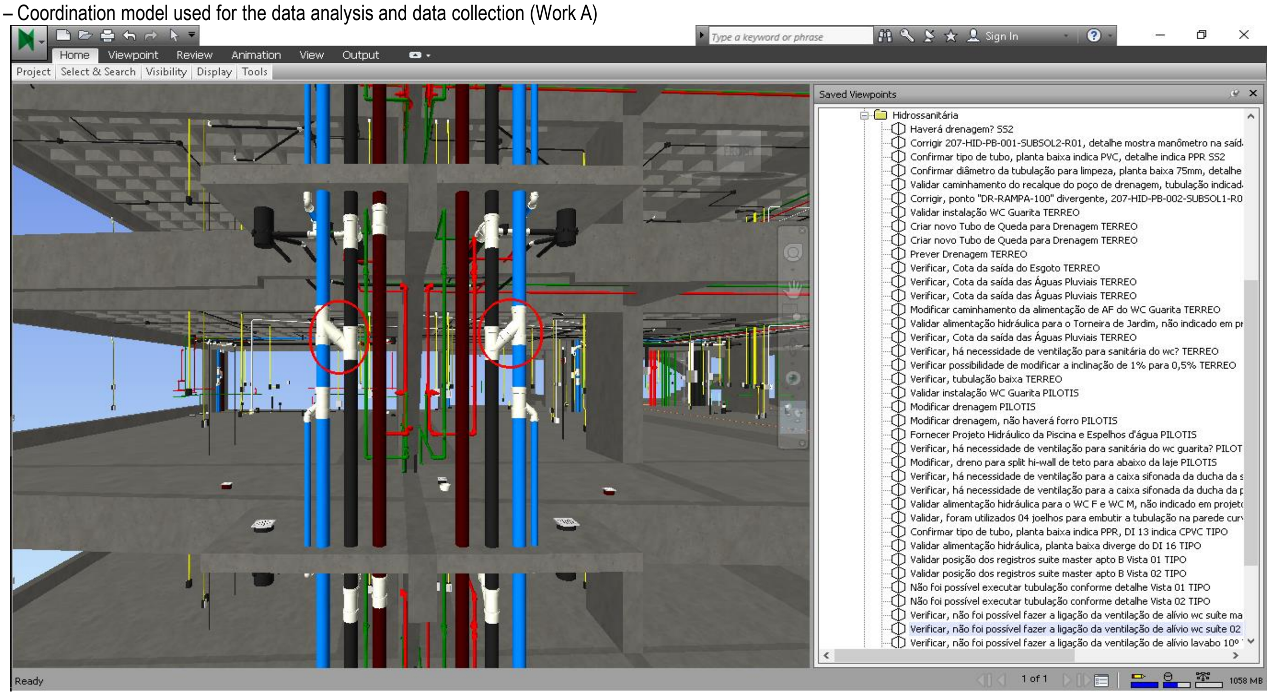
To maximize how useful information could be to the research goals, the case study selection considered an information-oriented choice (TAKAHASHI, 2013). This directed the case study to be applied in a Brazilian design company known for its tradition, design competence and market leadership in VDC. Two multifamily residential buildings, 3D coordinated and virtually prototyped by this company, were selected as units of study.

Therefore, the data collection was based on multiple evidence sources: documental analysis and interviews. The former happened through virtual construction models composed by architectural, structural and installation models, as well as, Request For Information, that is, the coordination model.

The two residential multifamily building ventures had available 3D models based on Naviswork Freedom software with reports and issues summary of the design review process. Altogether, there were six navigation models, three for each unit of study, that is, residential multifamily buildings.

Figure 2 shows an example of the Naviswork interface, which supported the analysis. On the left, it can be verified insufficient distance to connect plumbing, while on the right, there is a RFI panel that allows navigating by the model through all the occurrences reported by the virtual construction team coordinator. Each RFI was matched to the prognostic basis, proposed by Dantas Filho et al. (2016) as described on Table 1.

Figure 2 – Coordination model used for the data analysis and data collection (Work A)



Hidrossanitária
- Haverá drenagem? SS2
- Corrigir 207-HID-PB-001-SUBSOL2-R01, detalhe mostra manômetro na saíd
- Confirmar tipo de tubo, planta baixa indica PVC, detalhe indica PPR SS2
- Confirmar diâmetro da tubulação para limpeza, planta baixa 75mm, detalhe
- Validar caminhamento do recalque do poço de drenagem, tubulação indicad
- Corrigir, ponto "DR-RAMPA-100" divergente, 207-HID-PB-002-SUBSOL1-R0
- Validar instalação WC Guarita TERREO
- Criar novo Tubo de Queda para Drenagem TERREO
- Criar novo Tubo de Queda para Drenagem TERREO
- Prever Drenagem TERREO
- Verificar, Cota da saída do Esgoto TERREO
- Verificar, Cota da saída das Águas Pluviais TERREO
- Verificar, Cota da saída das Águas Pluviais TERREO
- Modificar caminhamento da alimentação de AF do WC Guarita TERREO
- Validar alimentação hidráulica para o Torneira de Jardim, não indicado em pr
- Verificar, Cota da saída das Águas Pluviais TERREO
- Verificar, há necessidade de ventilação para sanitária do wc? TERREO
- Verificar possibilidade de modificar a inclinação de 1% para 0,5% TERREO
- Verificar, tubulação baixa TERREO
- Validar instalação WC Guarita PILOTIS
- Modificar drenagem PILOTIS
- Modificar drenagem, não haverá forro PILOTIS
- Fornecer Projeto Hidráulico da Piscina e Espelhos d'água PILOTIS
- Verificar, há necessidade de ventilação para sanitária do wc guarita? PILOT
- Modificar, dreno para split hi-wall de teto para abaixo da laje PILOTIS
- Verificar, há necessidade de ventilação para a caixa sifonada da ducha da s
- Verificar, há necessidade de ventilação para a caixa sifonada da ducha da p
- Validar alimentação hidráulica para o WC F e WC M, não indicado em projet
- Validar, foram utilizados 04 joelhos para embutir a tubulação na parede cur
- Confirmar tipo de tubo, planta baixa indica PPR, DI 13 indica CPVC TIPO
- Validar alimentação hidráulica, planta baixa diverge do DI 16 TIPO
- Validar posição dos registros suite master apto B Vista 01 TIPO
- Validar posição dos registros suite master apto B Vista 02 TIPO
- Não foi possível executar tubulação conforme detalhe Vista 01 TIPO
- Não foi possível executar tubulação conforme detalhe Vista 02 TIPO
- Verificar, não foi possível fazer a ligação da ventilação de alívio wc suíte ma
- Verificar, não foi possível fazer a ligação da ventilação de alívio wc suíte 02
- Verificar, não foi possível fazer a ligação da ventilação de alívio lavabo 10º

Source: The authors

A classification scheme to analyze residential design RFIs was proposed based on (HANLON; SANVIDO, 1995; JIANG; SOLNOSKY; LEICHT, 2013; DANTAS FILHO et al., 2015, 2016). This classification scheme is detailed in Dantas Filho et al (2015). The analysis categories are based on RFI categories such as: design correction, information divergence, design omission, design verification (Tabel 1).

Table 1 – RFI Categories

	RFI Categories	Definition
1	**Design Correction**	Problems associated to the solution execution presented at the design
2	**Design Omission**	The absence of necessary spefic design for some areas
3	**Design Verification**	Low complex issues that make design confusing. Opportunity for design enhancement
4	**Information Divergence**	Design mistake associated to lack of attention, in the same discipline, two or more different drawings

Source: Dantas Filho et al. (2016)

It is essential to highlight the adopted prognostic basis here is exploratory, qualitative and not generalized. What has been proposed so far is a picture of the variables and how they interfere in the design process.

Semi-structured interviews were conducted with the virtual construction team coordinator. The interviews were transcribed and transformed in process map, specially, explicating how Request For Information were generated and how the interaction among the designers occurs.

Results and discussion

Case study description

The company where the case study was applied has 500.000 m² area of VDC, distributed in 15 multifamily residential buildings, of 10 different incorporators situated in the northeast region of Brazil. The service delivery scope of this company excludes authoring, including virtual prototyping to support design coordination and material quantity extraction.

The units of study (Figures 3 and 4) were multifamily residential buildings each with more than 20 thousand square meters, designed by the same design team, whose characteristics are listed as follows in Table 2. The case study A was composed of one tower and the case study B of two towers. Figures 3 and 4 were taken from the Naviswork models that supported data collection.

Table 2 – Case study characteristics

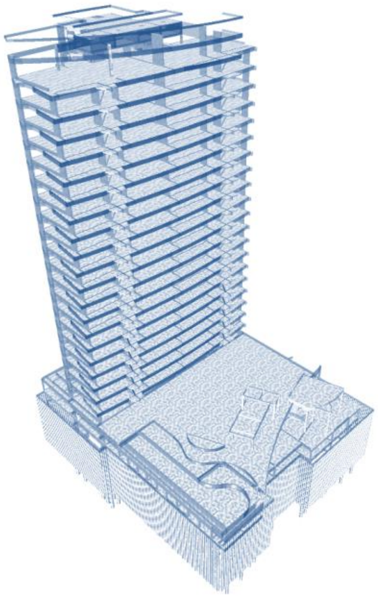
Characteristics	Work A	Work B
Total area (m²)	20.600,00	28.150,00
Recreation area (m²)	3.000,00	5.900,00
Private area (m²)	245,00	165,00
Quantity of towers	01	02
Quantity of floors	19	19
Quantity of units	38	76
Quantity of underground floors	02	02
RFI quantity	252	180

Source: The authors

The interview analysis, with the virtual construction team coordinator of these case studies, showed the virtual prototype and 3D coordination process map in three stages (Figure 5) involving: the developer and investor, the virtual construction team, and the design team. In the first stage, architecture and structure models are prototyped and analyzed by the virtual construction team and a coordination model is exchanged with the developer and with the design team. In the second stage, installation models are prototyped, added, and analyzed by the virtual construction team and again a coordination model is exchanged with the developer and with the design team. In the third stage, the virtual construction team updates the composed model, with updated solutions delivered by the design team considering the requested design changes. The composed model is validated and the virtual construction team delivers the final coordination model to the developer (investor) to be used in the construction site in order to promote improved practice and efficiency.

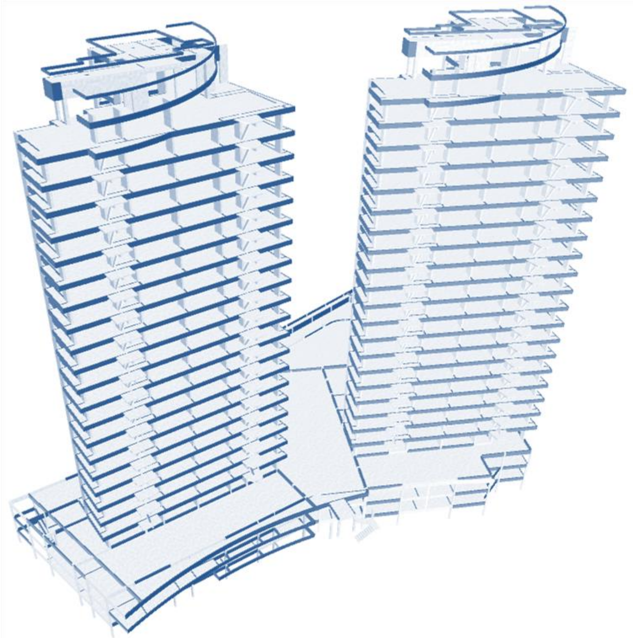
During each stage, the developers (and investor) and designers receive a coordination model in the Naviswork Freedom software-based navigation model with the composite model and the Request For Information resulted from the analysis of design coordination.

Figure 3 –Case A overview



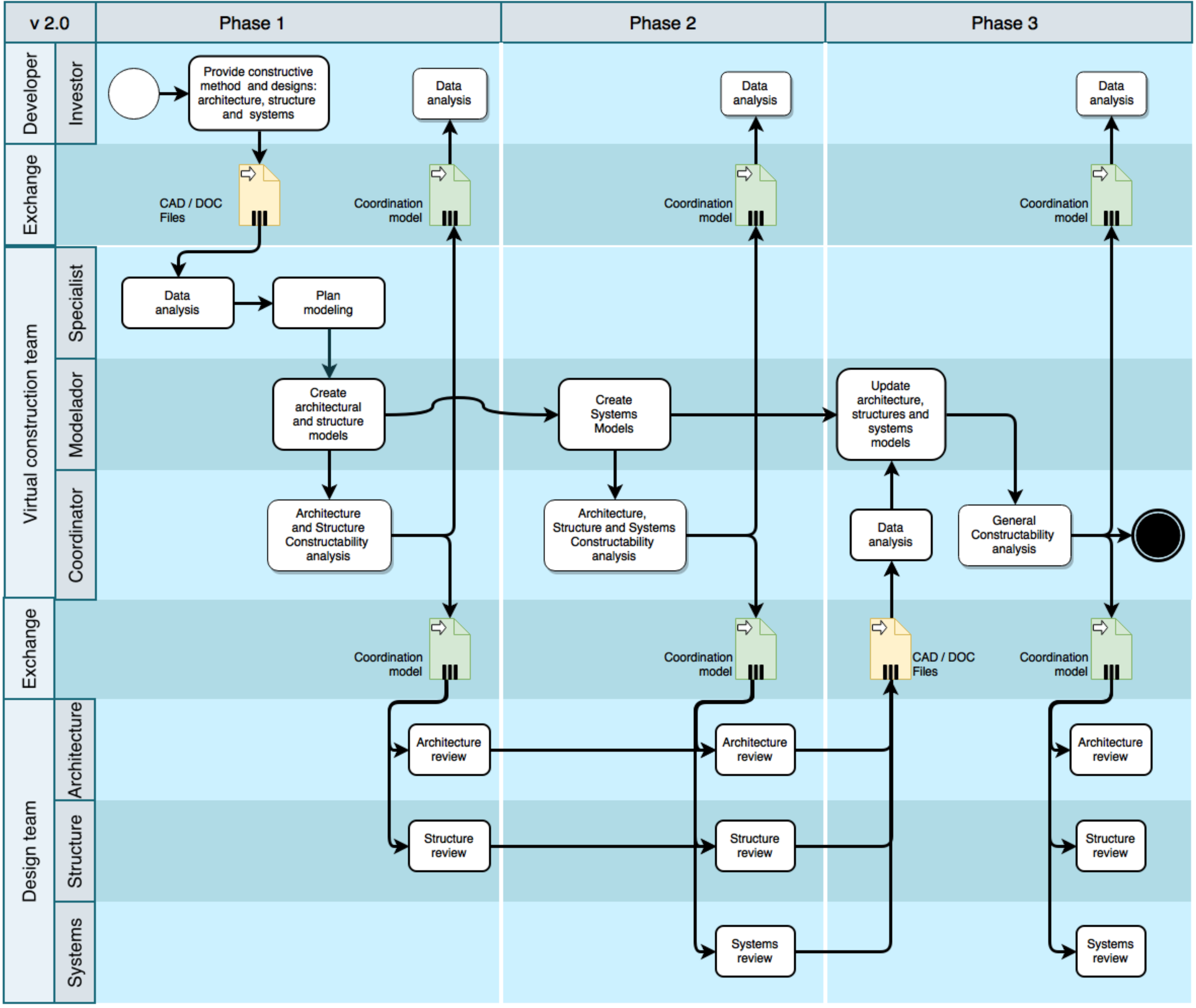
Source: The authors

Figure 4 –Case B overview



Source: The authors

Figure 5 – Virtual prototype and 3D coordination process flow



Source: The authors

In each phase, the designers are in charge of revising their corresponding design solution considering the RFI received. New design versions are created and, then, evaluated by the virtual construction team. The final report is delivered to the developer (and investor) and designers, including the unsolved RFIs or the new issues that came up because of the suggested changes.

In relation to the virtual construction team, three different roles were observed: the specialist, the modeler and the coordinator. The specialist checks if the design documents are complete and organizes the modeling process. The modeler creates the BIM models based on received CAD files, documents and modeling plan. The modelers may reports on design inconsistencies observed in the modeling process. The coordinator performs the constructability[1] analysis issuing RFIs. These RFIs can be due to: incomplete documentation, design inconsistencies observed in the modeling process and clash detection errors. This process is known as the constructability analysis flow[1].

In traditional design processes, without BIM or VDC, RFIs are generated along the building execution. Therefore, the cost of making changes dramatically increases as the project progresses (CURT, 2004). In the case studied here, the RFIs are generated before construction starts, allowing the designs to be revised as a whole. For this reason, the cost of making design changes are smaller.

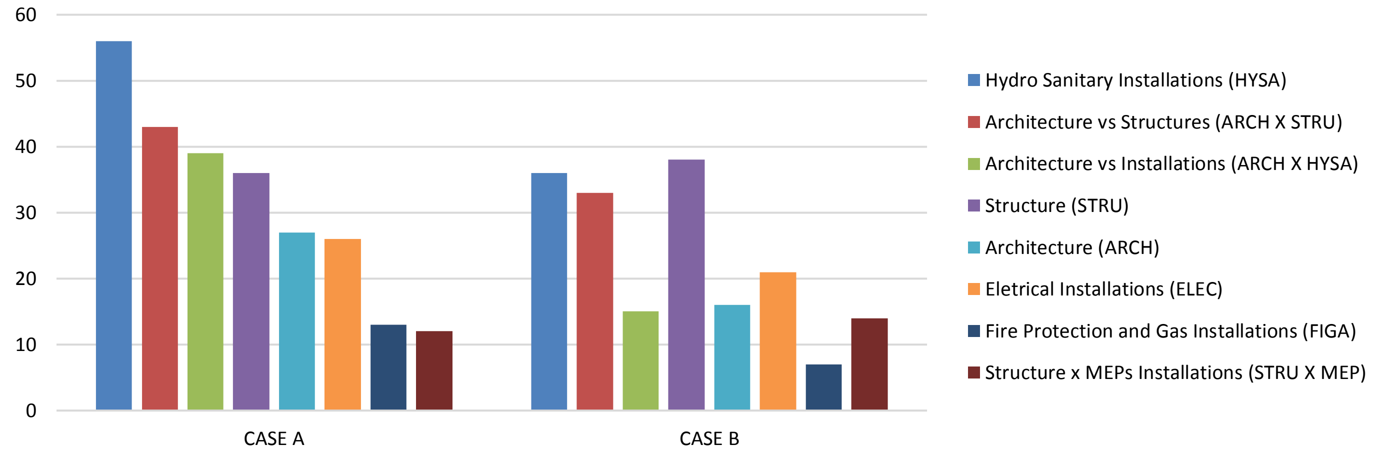
RFI Distribution

432 RFIs were identified and analyzed in the case studies. Some of them were related to only one discipline, for

example, either architecture or structure or installation design errors. Others were related to more than one discipline, for example, issues between architecture-structure, architecture-installation, and structure-installation. The virtual construction team coordinator executing constructability analysis generates these issues.

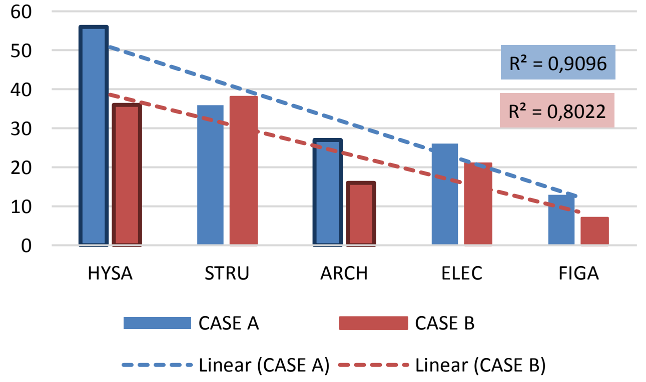
When analyzing the RFIs in numbers by design types comparing both cases studies the following was observed. Ordering RFIs in descending numbers, considering the resulting design types ordering of case study A as reference and comparing with the corresponding ordering of case study B it could be observed that different RFI distributions are presented (Figure 6). However, it is observed a decrease of RFI quantity from case A to case B in 4 out of 5 isolated design issues (Figure 7) and in 2 out of 3 interface design issues (Figure 8).

Figure 6 – RFI quantities by design types



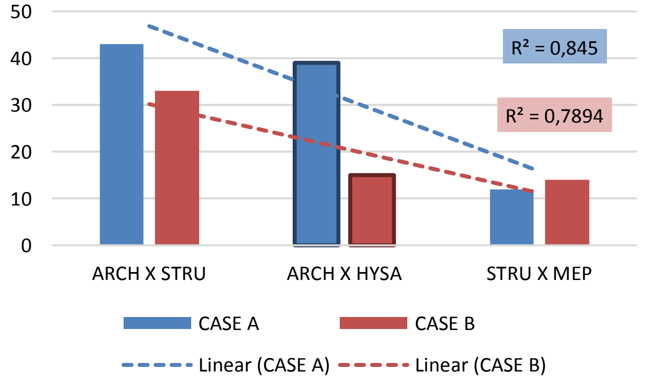
Source: The authors

Figure 7 – Ordering quantities of RFI related to isolated design discipline



Source: The authors

Figure 8 - Ordering quantities of RFI related to interface between design



Source: The authors

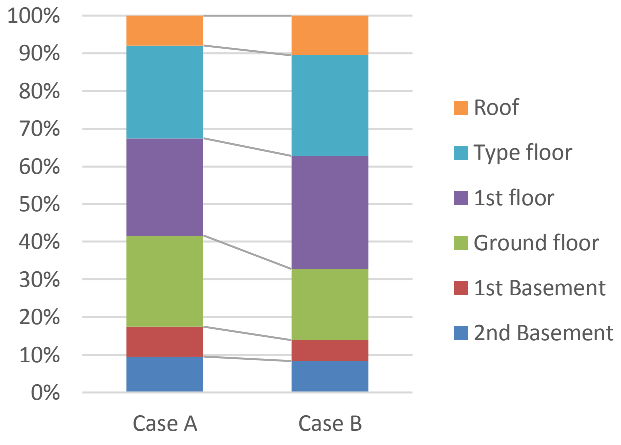
However, it was possible to extract a pattern of distribution of RFIs among the number design issues related to isolate discipline, been the Hydro Sanitary Installation and Structural design the disciplines that most benefits with 3D coordination in the case study of residential towers (Figure 7).

It was also possible to extract a weaker pattern of distribution quantities of RFIs among the design issues related to the interface of disciplines, been the issues related to the interface of Architecture and Structure the design interface that most benefits with 3D coordination in the case study of residential towers (Figure 8).

It was observed a decrease of RFI quantity from case A to case B in most of design issues (Figure 7 and 8). The interviews pointed that designs were done by the same architecture, structure and installation professionals, with the case A design review realized before of case B design review. That evidences a learning process that may have contributed not only to the virtual prototyping and reviewing process of the virtual construction team, but may also have helped the design team avoid possible RFIs in their own design solution, highlighting the disciplines of Hydro Sanitary Installations and Architecture, which presented the greatest decrease of RFIs from case A to case B (Figure 7 and 8).

Figure 9 shows the percentage of RFI in relation to the building vertical location.

Figure 9 –RFI types by building location



Source: The authors

It is clear that in both cases the lowest RFI percentages are on the first and second basement and roof levels. While the ground floor, the first floor with recreation items and the typical floor concentrate a greater amount of the RFI total. It is verified the replication of this distribution for cases A and B. Intuitively, it is important to solve typical floor questions, that is so because, in residential building, this floor execution is going to be repeated over and over. However, the RFI distribution in these locations points to the importance of also solving the ground floor and the recreational first floor questions. Ground floor and the recreational first floor are about large areas with function diversity, to where all tower installations converge.

Table 3 – Case study's evidences of RFI types

RFI types	**RFI evidences**		**RFI**
	Case Study A	**Case Study B**	**N.**
Design Correction	Conflict, Square Frame and Structure, Antechamber	Column Interfering Parking spaces 01 and 02	1
	Conflict between Plumb, Alarm and Telephone TYPE	Conflict Luminaire X Ground floor stairway	2
	Correct, DR/AP and VP Points do not match with Type Points	Correct P14 30x60 Dimension to 30x65 Basement	3
	Resize Shafts TYPE	Reposition SS1 Slots	4
	Sewage pipeline under the ceiling H=2.37m Bone TYPE	Reposition Ribs Ground Floor	5
	Revise the ceiling height, Siphoned Box, Visible Suite Master TYPE	Correct Form: P13 P17 columns / V126 V130 beams Ground Floor	6
	Gas Gauge Located in the Shaft Room, Without Ventilation TYPE	Conflict Pipeline X SS1 E Door Ground Floor	7
	Anticipate Shaft BASEMENT	Conflict Pipeline X Type Column	8
Design Omission	How is unevenness going to be fixed? (ramp?) Ground Floor	Anticipate Slab between the V318 and V319 beams	9
	Is the floor going to be over the landfill or is there going to be slab? Ground Floor	How is ventilation going be in the bathrooms?	10
	Analyze, what is the ceiling final touch going to be like? Basement	How is trash unevenness going to be fixed? Ground Floor	11
	Analyze, will there be any filling? Type	Define Square Frames Sauna Basement	12
	How is the metal structure going to be fixed on the front?	Brickwork without structural support Ground Floor	13
	Point shelter to control elevating platform Ground Floor	Anticipate electric feeding for all outlets in the Basement	14
	Will there be drainage? ss2	Anticipate Drainage, Sentry-house and Barbecue Area Basement	15
	Double brickwork to build in flushing box Basement	Anticipate Slab Ground Floor	16
Design Verification	Revise Basement Stairway to the First Type H=3.42m View 01 1° TYPE	Are the columns going to "die" on the lowered slab? Basement	17
	Verify Architecture X Structure conflict TYPE	Confirm Elevator Shaft Measures TS	18
	Constructive Method Brickwork 30cm TYPE	Analyze width < 1.20m Type	19
	Analyze Contention on the Swing Segment GROUND FLOOR	Confirm Diameter reduction 200 X 150mm Ground Floor	20
	Verify, Rainwater Outlet Quota GROUND FLOOR	Indicate AP3 and TG4 transition TN Basement	21
	Verify the need of sprinkler in the useless area on the ground floor	Is there the need of Sprinkler on the SS2 ramp?	22
	Validate WC Installation Sentry-house BASEMENT	Document the pipeline way Basement Tower S Ground Floor	23
	Verify, is there the need of ventilation for the siphoned box of the sauna shower? Basement	Document Pressurizer Roof	24
Design Divergence	Verify, Pool shape in the structure is divergent from the architecture BASEMENT	Column out of alignment Ground Floor Basement	25
	Anticipate Pergolas in the Structural Design GROUND FLOOR	V27 Width 15 or 18cm? Type	26
	Out of Alignment Architecture X Structure GROUND FLOOR	V60 Width 22 or 25cm? Roof	27
	Divergence, Architecture H=2.90m, Structure 2.78m BASEMENT	Out of Alignment Architecture X Structure Basement	28
	Confirm Tube type, Ground Plan Indicates PVC, Detail Indicates PPR SS2	Out of Alignment Structure X Architecture Roof	28
	Update Architect basis in the electrical design and make the necessary alterations SS2	Will there be Grill? It was anticipated on the HIS Ground Floor	30
	Divergence on the Box dimension, 207- 60x60x15; 80x80x15 ROOF	Communication point executed according to vertical schema, Not Documented on PB SS2	31
	Confirm Clean-up Pipeline Diameter, Ground Plan 75mm, Detail 75mm, Vertical Schema 63mm SS2	Divergence Box in PB 40x40 and ESQVERT 30x30 ROOF	32

Source: The authors

RFI Classification

This section is about the exploratory RFI analysis of the case studies. Table 3 presents the classification of observer RFIs into the categories of design: correction, omission, verification and divergence, followed by the summarized description of each issue. Examples of each type of IRF categories will exemplified in a figure and narrative.

Figure 10 refers to a design correction RFI, seen in both case studies. It can be noticed that a column is in conflict with a basement parking space. This kind of RFI can result from conflicts that can be identified either manually or using automatic clash detection. Some examples of RFIs classified as correction and present in both case studies can be seen in Table 3, lines 1-8.

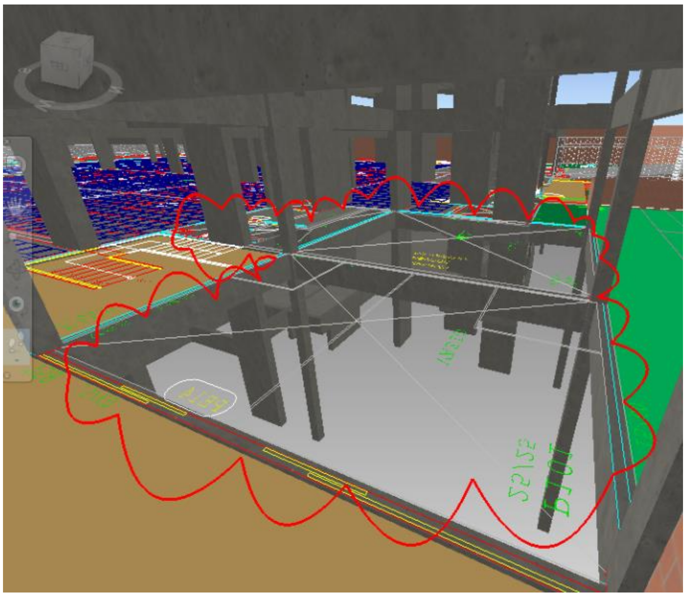
Figure 10 - RFI Examples of Correction

Source: The authors

In Figure 11, is related to a RFI classified as design omission due to the absence of design structural definition about how the floor in the highlighted area is going to be executed. In this case, there is the absence of design definition about if there will be a concrete ballast over the ground or if there will be a floor slab. This information absence was identified by manual detection and it reveals itself as a challenge of automatic detection rule creation. Other examples are shown in Table 3, lines 9-16.

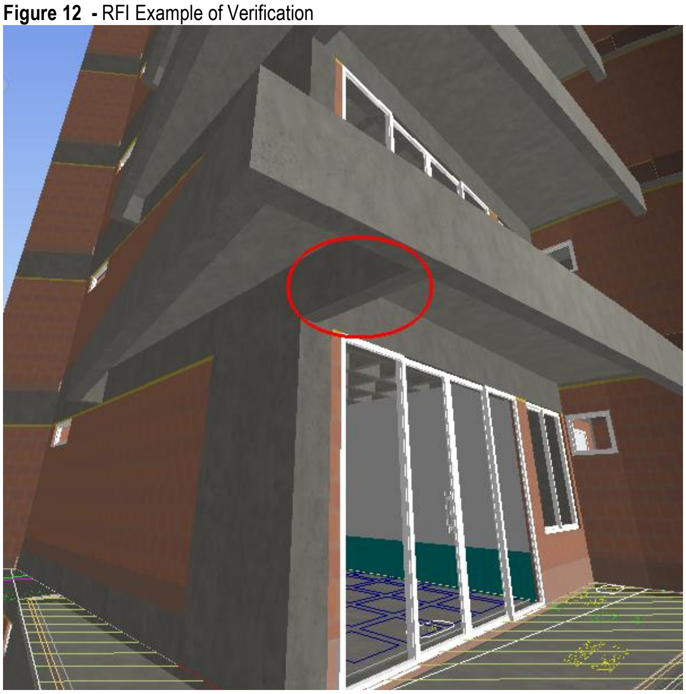
Figure 12 evidences RFI classified as design verification, present in both cases. It is possible to observe the structural design is not wrong, but the fact of the beams being the same height, that makes the roof installation unviable without the proper final touch of the edge beam. Other examples are shown in Table 3, lines 17-24.

Figure 11 - RFI Example of Omission



Source: The authors

Figure 12 - RFI Example of Verification



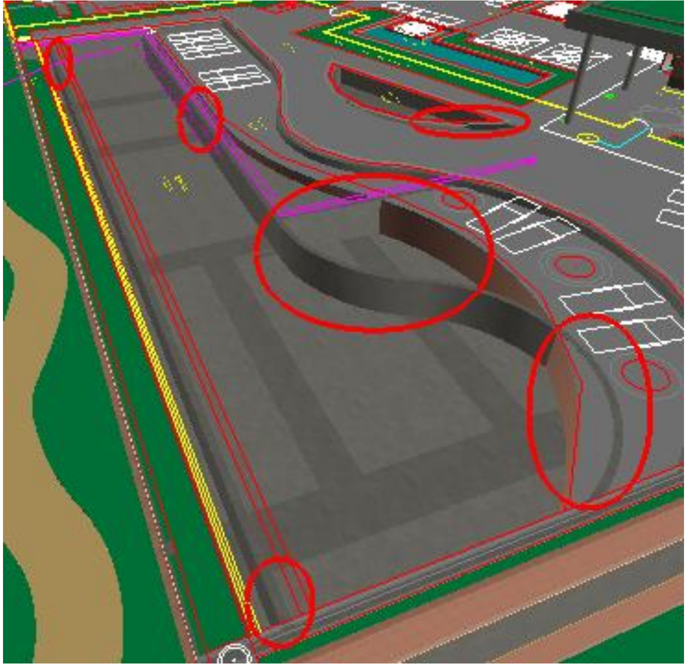
Source: The authors

Figure 13 shows RFI classified as divergence. It is observed that the walls in the structural model in the swimming pool area presents a different form of that indicated by architecture model. This is another challenging type of detection rule creation of automatic conflict, because discipline elements of different designs may coincide. Other examples of this classification are shown in Table 3, lines 25-32.

Figure 14 presents the distribution of the RFI types identified in each category. It is observed that, in both cases, correction RFIs are more numerous. On the other hand, omission, verification and divergence RFIs, when grouped, are as numerous as the largest classification.

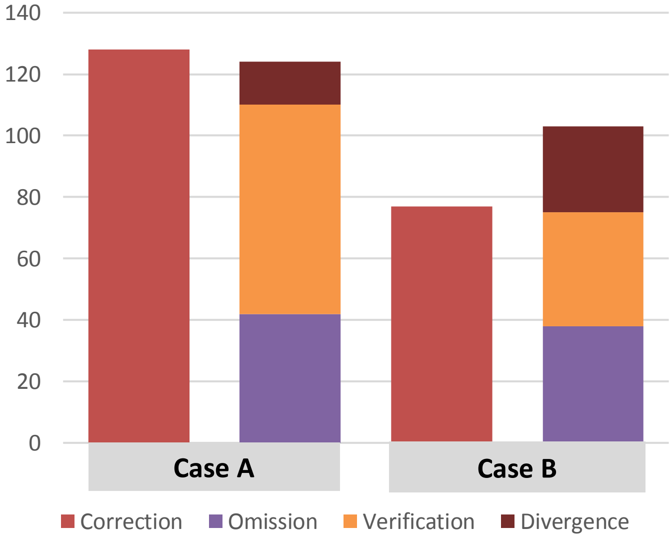
Similar results were obtained from the two cases, it can be said that a replication occurred indicating a pattern.

Figure 13 - RFI Examples of Divergence



Source: The authors

Figure **14** – RFI classification by case



Source: The authors

The omission, verification and divergence RFIs can be a challenge for automatic detection rule creation, because they are not resulted by geometry clashes. Then, manual detection stands up as a method of identification.

The analyzed designs were carried out by companies that have stability and quality in the market, this way, the results can be applied in other companies as well.

Limitations of the research

The study was developed as a case study; therefore, findings cannot be generalized. However, hypotheses can be drawn. The study was applied to high-rise residential buildings. Thus in another typology, for example, horizontal housing developments, the distribution of RFIs by location may differ.

However, the realization of case study does not propose to enumerate frequencies and make a statistical generalization. But rather indicate that the theoretical proposition that RFIs can be classified contributing to understanding the problem and promote learning.

Conclusion

The qualitative research carried out in this work on Request for information shows patterns of behavior adding richness and depth the understanding the design review of residential towers. The design process map drawn with the IDM methodology shows a partially implemented VDC where design developed with traditional CAD tools benefits from a design review process developed with virtual prototyping and 3D coordination with BIM tools. In relation to RFIs types' distribution – correction, omission, verification and divergence - it has been observed design issues locations are recurrent between the case studies (Figure 9) and that the correction RFI type is the most frequent (Figure 14). Also it was observed that the verification RFI decreased from case study A to B giving space the divergence type of RFI (Figure 14). This may be due to the learning process promoted by the VDC design review. Design issues were classified as to their causes from literature review by providing a holistic view and identifying issues for creating prevention strategies (LOPEZ et al., 2010). Clashes were classified as to their existence for the establishment of a common language that allows the sharing of lessons learned for the advancement of practice and the development of theory (TOMMELEIN; GHOLAMI, 2012).

In terms of RFI quantities distribution among design disciplines, it was possible to extract a pattern related to isolate discipline design issues, been the Hydro Sanitary Installation and Structural the disciplines that most gained with 3D coordination in the case study of residential towers (Figure 7). A weaker pattern of quantities distribution of RFIs among the design issues between disciplines indicated that issues related to the interface of Architecture and Structure most gained with 3D coordination in the case study of residential towers (Figure 8). The patterns of RFI quantities distribution behavior shows where improving design effort must be, exposing design complexity. New concepts are needed to understand how RFIs are distributed and how they occur so that this enables a learning process of the parties involved. However, some missing information, such as classification as cause or existence, would contribute to the development of prevention strategies as proposed by Love and Smith (2016).

It can be concluded that RFIs from residential tower VDC designs review are susceptible to be distributed and classified based on the interface, location and typology, whether of the type of correction, omission, verification or divergence. Considering that, residential tower designs are examples of built environment designs comprised of architecture, structure, and other installations designs, then, the analysis here presented apply to new situations other than those studied in order to promote the learning of and metrics for VDC.

Acknowledgments

We gratefully thank the anonymous reviewers for their constructive feedback to improve this paper. We also thank the editor, Regina Ruschel, for her helpful comments.

Notes

(1) Constructability can be defined as design optimization by the use of building knowledge and work planning experience (OTHMAN, 2011).

References

AL HATTAB, M.; HAMZEH, F. Using social network theory and simulation to compare traditional versus BIM–lean practice for design error management. **Automation in Construction**, v. 52, p. 59–69, abr. 2015. Disponível em: <http://www.sciencedirect.com/science/article/pii/S0926580515000333>. Acesso em: 4 jan. 2016.

AL HATTAB, M.; HAMZEH, F. R. Information flow comparison between traditional and BIM-based projects in the design phase. **Proceedings for the 21st Annual Conference of the International Group for Lean Construction**, n. June 2015, p. 761–770, 2013. Disponível em: <https://www.dropbox.com/s/ztfesa6s7anq1na/HATTAB HAMZEH 2013 Information flow comparison between traditional and BIM-based projects in the .pdf>.

ANTUNES, C. E.; SCHEER, S. Requisitos de informação e mapas do processo de projeto de estruturas em concreto armado: um estudo de caso utilizando a metodologia IDM. **PARC Pesquisa em Arquitetura e Construção**, v. 5, n. 1, p. 18–34, 2014. Disponível em: <http://periodicos.sbu.unicamp.br/ojs/index.php/parc/article/view/8634541/2462>.

ARAM, S.; EASTMAN, C.; SACKS, R. Requirements for BIM platforms in the concrete reinforcement supply chain. **Automation in Construction**, v. 35, p. 1–17, nov. 2013. Disponível em: <http://www.sciencedirect.com/science/article/pii/S092658051300023X>. Acesso em: 23 ago. 2015.

AZHAR, S.; NADEEM, A.; MOK, J. Y.; LEUNG, B. H. Building Information Modeling (BIM): A new paradigm for visual interactive modeling and simulation for construction projects. In: Proc., First International Conference on Construction in Developing Countries, Karachi, Pakistan. **Anais**... Karachi, Pakistan: 2008. Disponível em: <http://goo.gl/iBbPf7>.p.435–446

BELLAN, M.; FABRICIO, M. M. Práticas e ferramentas gerenciais de apoio a integração e coordenação de projetos. **PARC Pesquisa em Arquitetura e Construção**, v. 1, n. 5, p. 27, 2010. Disponível em: <http://www.fec.unicamp.br/~parc/vol1/n5/vol1-n5-BELLAN-FABRICIO.pdf>.

BIOTTO, C. N.; FORMOSO, C. T.; ISATTO, E. L. O Uso da Modelagem BIM 4D no Projeto e Gestão de Sistemas de Produção em Empreendimentos de Construção. **Ambiente Construído**, v. 15, n. 2, p. 65–77, 2015. Disponível em: <http://seer.ufrgs.br/index.php/ambienteconstruido/article/view/38333>.

BRITO, D. M. De; ANDRADE, E. De; FERREIRA, M. Avaliação de estratégias para representação e análise do planejamento e controle de obras utilizando modelos BIM 4D. **Ambiente Construído**, v. 15, p. 203–223, 2015. Disponível em: <http://dx.doi.org/10.1590/s1678-86212015000400047>.

BUILDINGSMART. Information Delivery Manual Guide to Components and Development Methods. **buildingSMART**, p. 1–84, 2010.

CHEN, L.; LUO, H. A BIM-based construction quality management model and its applications. **Automation in Construction**, v. 46, p. 64–73, 2014. Disponível em: <http://dx.doi.org/10.1016/j.autcon.2014.05.009>.

CHIN, C. Work-in-Process and Construction Project Information Flows. In: Proceedings for the 17th Annual Conference of the International Group for Lean Construction, Table 1, Taipei, Taiwan. **Anais**... Taipei, Taiwan: 2009. Disponível em: <http://www.iglc.net/Papers/Details/629>.p.257–266

CHUA, D. K. H.; YEOH, J. K. W. Understanding the Science of Virtual Design and Construction: What It Takes to Go beyond Building Information Modeling. **Computing in Civil Engineering 2015**, p. 1, 2015. Disponível em: <http://dx.doi.org/10.1061/9780784407943>.

CURT. **Collaboration, Integrated Information and the Project Lifecycle in Building Design, Construction and Operation**. [s.l: s.n.]. Disponível em: <http://codebim.com/wp-content/uploads/2013/06/CurtCollaboration.pdf>.

DANTAS FILHO, J. B. P.; ANGELIM, B. M.; GUEDES, J. P.; FARIAS DE CASTRO, M. A.; BARROS NETO, J. de P. Virtual Design and Construction of Plumbing Systems. In: International Conference on engineering - Engineerinf for Society, COVILHÃ. **Anais**... COVILHÃ: 2015. Disponível em: <https://goo.gl/nZeYfV>.

DANTAS FILHO, J. B. P.; ANGELIM, B. M.; GUEDES, J. P.; SILVEIRA, S. S.; NETO, J. de P. B. Constructability Analysis of Architecture–Structure Interface Based on BIM. In: 24th Annual Conference of the International Group for Lean Construction, Boston. **Anais**... Boston: 2016. Disponível em: <http://www.iglc.net/papers/details/1273>.

DEBS, L. de C. El; FERREIRA, S. L. Diretrizes para processo de projeto de fachadas com painéis pré-fabricados de concreto em ambiente BIM. **Ambiente Construído**, v. 14, n. 2, p. 41–60, 2014. Disponível em: <http://ref.scielo.org/h6ccwm>.

DEZAN, W. V. BIM no desenvolvimento de projeto: o caso prático do Centro de Engenharia Molecular e Celular do Centro Infantil Boldrini. **PARC Pesquisa em Arquitetura e Construção**, v. 5, p. 52–61, 2014. Disponível em: <http://periodicos.sbu.unicamp.br/ojs/index.php/parc/article/view/8634544>.

DEZEN-KEMPTER, E.; SOIBELMAN, L.; CHEN, M.; VICTOR, A.; FILHO, M. Escaneamento 3D a laser, fotogrametria e modelagem da informação da construção para gestão e operação de edificações históricas. **Gestão e Tecnologia de Projetos**, v. 10, n. 2, p. 113–124, 2015. Disponível em: <http://dx.doi.org.br/10.11606/gtp.v10i2.102710\nhttp://dx.doi.org/10.11606/gtp.v10i2.102710>.

EASTMAN, C. M. C.; TEICHOLZ, P.; SACKS, R.; LISTON, K. **Bim handbook: a guide to building information modeling for owners, managers, designers, engineers and contractors**. 2nd ed. ed. New Jersey: John Wiley & Sons, 2011.

FARINA, H.; COELHO, K. M. Impactos Na Coordenação De Projetos Assistida Pela Modelagem Da Informação Da Construção. In: VII Encontro de Tecnologia de Informação e Comunicação na Construção - Edificações, Infra-estrutura e Cidade: Do BIM ao CIM, 2, Recife. **Anais**... Recife: 2015. Disponível em: <http://www.proceedings.blucher.com.br/article-details/impactos-na-coordenao-de-projetos-assistida-pela-modelagem-da-informao-da-construo-20516>.p.61–74

HANLON, E. J.; SANVIDO, V. E. Constructability information classification scheme. **Journal of construction engineering and management**, v. 121, n. 4, p. 337–345, 1995. Disponível em: <http://ascelibrary.org/doi/abs/10.1061/(ASCE)0733-9364(1995)121:4(337)>.

HUGHES, N.; WELLS, M.; NUTTER, C.; ZACK, J. **Impact & control of RFIs on construction projects.Navigant Construction Forum™**. [s.l: s.n.]. Disponível em: <http://goo.gl/unXqaU>.

JIANG, L.; SOLNOSKY, R.; LEICHT, R. M. Virtual Prototyping for Constructability Review. In: 4th Construction Specialty Conference, Montreal. **Anais**... Montreal: 2013. Disponível em: <https://goo.gl/hTsCEk>.p.11

KAM, C.; FISCHER, M. Capitalizing on early project decision-making opportunities to improve facility design, construction, and life-cycle performance - POP, PM4D, and decision dashboard approaches. **Automation in Construction**, v. 13, n. 1, p. 53–65, 2004.

KEHL, C.; ISATTO, E. L. Barreiras e oportunidades para a verificação automática de regras da produção na fase de projeto com uso da tecnologia BIM. **VII Encontro de Tecnologia de Informação e Comunicação na Construção - Edificações, Infra-estrutura e Cidade: Do BIM ao CIM**, v. 2, n. 2, p. 13–26, 2015. Disponível em: <http://www.proceedings.blucher.com.br/article-details/barreiras-e-oportunidades-para-a-verificao-automtica-de-regras-da-

produo-na-fase-de-projeto-com-uso-da-tecnologia-bim-20512>.

LEITE, F.; AKCAMETE, A.; AKINCI, B.; ATASOY, G.; KIZILTAS, S. Analysis of modeling effort and impact of different levels of detail in building information models. **Automation in Construction**, v. 20, n. 5, p. 601–609, 2011. Disponível em: <http://dx.doi.org/10.1016/j.autcon.2010.11.027>.

LEITE, F.; AKINCI, B.; GARRETT, J. Identification of data items needed for automatic clash detection in MEP design coordination. In: 2009 Construction Research Congress, **Anais**...2009. Disponível em: <http://ascelibrary.org/doi/pdf/10.1061/41020(339)43>.p.416–425

LOPEZ, R.; LOVE, P. E. D.; EDWARDS, D. J.; DAVIS, P. R. Design error classification, causation, and prevention in construction engineering. **Journal of performance of constructed facilities**, v. 24, n. 4, p. 399–408, 2010. Disponível em: <https://goo.gl/kw6iyz>.

LOVE, P. E. D.; SMITH, J. Error management: implications for construction. **Construction Innovation**, v. 16, n. 4, p. 418–424, 2016. Disponível em: <http://www.emeraldinsight.com/doi/10.1108/CI-01-2016-0001>.

MONTEIRO, A.; FERREIRA, R. C.; SANTOS, E. T. Representation Paradigms for Masonry Modulation in Bim Tools. **Gestão & Tecnologia de Projetos**, v. 4, n. 2, 2009. Disponível em: <http://www.revistas.usp.br/gestaodeprojetos/article/view/50959>.

MORORÓ, M. S. de M.; ROMCY, N. M. e S.; CARDOSO, D. R.; BARROS NETO, J. de P. Proposta paramétrica para projetos sustentáveis de Habitação de Interesse Social em ambiente BIM. **Ambiente Construído**, v. 16, n. 4, p. 27–44, 2016. Disponível em: <http://dx.doi.org/10.1590/s1678-86212016000400103>.

NATH, T.; ATTARZADEH, M.; TIONG, R. L. K.; CHIDAMBARAM, C.; YU, Z. Productivity improvement of precast shop drawings generation through BIM-based process re-engineering. **Automation in Construction**, v. 54, n. JUNE, p. 54–68, 2015. Disponível em: <http://dx.doi.org/10.1016/j.autcon.2015.03.014>.

NEIVA NETO, R. D. S.; FARIA, B. L. DE; BIZELLO, S. A. Implantação de BIM em uma construtora de médio porte: caso prático, da modelagem a quantificação. **Revista Parc – Pesquisa Em Arquitetura E Construção**, v. 5, p. 45–51, 2014. Disponível em: <http://periodicos.sbu.unicamp.br/ojs/index.php/parc/article/view/8634543>.

NEIVA NETO, R. da S.; RUSCHEL, R. C. BIM aplicado ao projeto de fôrmas de madeira em estrutura de concreto armado. **Ambiente Construído**, p. 183–201a, 2015. Disponível em: <http://dx.doi.org/10.1590/s1678-86212015000400046>.

OTHMAN, A. A. E. Improving Building Performance through Integrating Constructability in the Design Process. **Organization, Technology and Management in Construction: An International Journal**, v. 3, n. 2, p. 333–347, 2011. Disponível em: <http://www.grad.unizg.hr/otmcj/clanci/vol3_is2/Clanak_6 OTMCJ_2_2011_web-5.pdf>.

PENTTILÄ, H. Describing the changes in architectural information technology to understand design complexity and free-form architectural expression. **ITCON**, v. 11, n. January, p. 395–408, 2006. Disponível em: <http://www.itcon.org/2006/29>.

RILEY, D.; HORMAN, M. The effects of design coordination on project uncertainty. **Proceedings of the 9th Annual Conference of the International Group for Lean Construction (IGLC-9), Singapore**, p. 1–8, 2001.

ROMCY, N. M. e S.; CARDOSO, D.; BERTINI, A. A.; PAES, A. Desenvolvimento de aplicativo em ambiente BIM, segundo princípios da Coordenação Modular. **Ambiente Construído**, v. 14, n. 2, p. 23–39, 2014. Disponível em: <http://seer.ufrgs.br/index.php/ambienteconstruido/article/view/42885>.

SACKS, R.; BARAK, R. Quantitative assessment of the impact of 3D modelling of building structures on engineering productivity. In: Joint International Conference on Computing and Decision Making in Civil and Building Engineering, Montréal. **Anais**... Montréal: 2006. Disponível em: <http://goo.gl/MivFaI>.p.1186–1195

SUCCAR, B. Building information modelling framework: A research and delivery foundation for industry stakeholders. **Automation in Construction**, v. 18, n. 3, p. 357–375, 2009. Disponível em: <http://dx.doi.org/10.1016/j.autcon.2008.10.003>.

TAKAHASHI, A. R. W. **Pesquisa qualitativa em administração -fundamentos, métodos e usos no brasil**. 1. ed. São

Paulo: ATLAS, 2013.

TOMMELEIN, I. D.; GHOLAMI, S. Root Causes of Clashes in Building Information Models. **Proceedings for the 20th Annual Conference of the International Group for Lean Construction.**, v. 1, n. 510, 2012.

YIN, R. K. **Estudo de caso:planejamento e métodos**. 2. ed. Porto Alegre: Bookman, 2001.

ZUPPA, D.; ISSA, R. R. A.; SUERMANN, P. C. BIM's impact on the success measures of construction projects. **Computing in Civil Engineering**, v. 2009, p. 503–512, 2009. Disponível em: <http://ascelibrary.org/doi/abs/10.1061/41052(346)50>.

---

[1] **João Bosco Pinheiro Dantas Filho**
Architect and Urbanist. Master of Science in Civil Engineering: Structure and Building Construction by Universidade Federal do Ceará - UFC. Corresponding address: Av. 13 de Maio, 2081 - Fatima, Fortaleza - CE, Brasil, CEP 60040-531

[2] **Bruno Maciel Angelim**
Civil Engineer. Specialist in Engineering Management by Universidade de Fortaleza - UNIFOR. Corresponding address: Av. 13 de Maio, 1116 - Sala 804 - Fatima, Fortaleza - CE, Brasil, CEP 60040-531

[3] **Joana Pimentel Guedes**
Architect and Urbanist. Corresponding address: Universidade Federal do Ceará, Centro de Tecnologia, Departamento de Engenharia Estrutural e Construção Civil. Campus do Pici, s/n - Bloco 728.

[4] **José de Paula Barros Neto**
Civil Engineer. Ph.D. in Administration. Corresponding address: Universidade Federal do Ceará, Centro de Tecnologia, Departamento de Engenharia Estrutural e Construção Civil. Campus do Pici, s/n - Bloco 728.