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Qualitative analysis of Request For Information to identify design flaws in steel construction projects

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Abstract: Request for information (RFI) is a formal process used in the Architecture, Engineering and Construction industry to address design flaws that affect communication between designers and contractors. A large number of RFIs are a sign of a lack of precision or coordination in the design documents. However, RFIs produce rich, precise, and structured information. Analyzing their content can help to identify recurring problems between designers and construction teams and better tailor future projects to the working context of the contractors. This article presents a method for identifying recurring issues during the design phase of steel construction projects through the analysis of the contents of RFIs. It is original in using a qualitative content analysis tool that can analyze large quantities of RFIs rapidly. Identifying the recurrent problems of contractors will allow the establishment of rules to be taken into consideration during the design phase of future steel construction projects. A case study of 26 steel construction projects demonstrates the feasibility of this method. This case study shows that, given the same designers and construction teams, recurring problems shown in RFIs do not differ according to the scale of the projects. In this case, the main issue between designers and contractors is the lack and inadequate presentation of information related to the connection of steel components. Identifying these problems can pave the way for initiatives to improve the design phase and can be an essential step in making contractors' knowledge available to designers early in the projects.

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1 Introduction

Many factors affect the success of a project in the Architecture, Engineering and Construction (AEC) industry and among which is the quality of collaboration between the designers and the construction teams (Latham Sir, 1994; Egan, 1998; Jin et al., 2018; Zaker and Coloma, 2018). Designers provide information that contractors will use to create a product that will satisfy the customers' needs (Tilley, 1998). Though 88% of the decisions concerning the duration and cost of the projects are made by the designers (Evers and Maatje, 2000), they often have little experience or knowledge to ensure the constructability of their design solutions. This situation results in design requirements that are incomplete, inadequate, or poorly coordinated for construction. Contractors, who usually integrate projects after completion of the design phase (Forgues and Iordanova, 2010; Barrett, 2016; Fokwa Soh et al., 2018), will formulate request for information (RFI) to obtain information regarding issues or lack of precision in the proposed design or to suggest better alternatives (Mohamed et al., 1999; Hughes et al., 2013). An RFI is, by definition, a formal document produced to request information or clarification from designers (Andrews, 2005). In a project, the quantity of RFIs is relative to the quality of the design (Mohamed et al., 1999; Papajohn et al., 2018; Fokwa Soh et al., 2019). The RFIs that contractors submit during a project are numerous and have a significant impact on the cost and duration of the project (Jeong et al., 2016; Fokwa Soh et al., 2017). We argue that design quality could be significantly improved, and the cost and duration of subsequent projects

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could be reduced by taking into account the information requested in the RFIs of the previous projects to improve future projects. To do so, this article suggests to use a summative qualitative analysis of the content of RFIs to highlight the information most-requested by the contractors. Once the problems are clearly identified, designers will be better equipped to deal with them and will provide better information in future projects. To this end, this article, which is an extended version of the paper presented during the Creative Construction Conference 2019 (Fokwa Soh et al., 2019), first shows the importance of involving contractors' requirements into the design phase to improve the construction processes and the significant role that RFIs can play in this improvement. It then presents a method that analyzes the textual contents of RFIs to highlight recurring problems. A case study is carried out in the steel construction industry. The results of this case study are analyzed and discussed later.

1.1 The importance of involving contractors' requirements into the design phase

The AEC industry is a dynamic and complex sector that brings together several stakeholders from different disciplines. Traditional AEC project delivery practices create many problems such as isolation of professionals, sequential work, and lack of coordination between design and construction resulting in fragmentation. Fragmentation is defined by Abadi (2005) as "the division resulting from the increasing number of both professions (i.e. architect, engineer) and organizations involved in all processes of a building project. This has been caused by the growing demand for differentiation and specialization as building projects increase in both size and complexity." The noninvolvement of contractors in the design phase and the increase in the need for contractor specialization for project implementation tend to increase the amount of waste, reduce the quality of the design phase documents, and increase the number of RFIs in AEC industry projects. This situation results in discussions and waste of time and money during the realization of projects (Abadi, 2005; Onungwa and Uduma-Olugu, 2017). Integrating the requirements and knowledge of contractors during the design phase would be a great asset to improve the quality of the design. This article proposes some standards to identify recurring problems between designers and contractors. These problems often emerge from the design documents.

1.2 Improve design documents to improve the construction industry process

Preceded by needs analysis, the design phase is one of the first phases of a project's life cycle in the AEC industry. The quality of the buildings in a construction project depends on the quality of the design documents (Burati et al., 1992; Abolnour, 1994; Crotty, 2012; Assaf et al., 2018; Hosny et al., 2019). A useful design document is defined as one that provides contractors with all the information required for efficient construction (Tilley, 1998; Assaf et al., 2018).

Inadequate design and documentation may lead to a poor quality project. Improper design is characterized by defects and ambiguities found in design documents (Lutz et al., 1990; Assaf et al., 2018; Fokwa Soh et al., 2019). These defects are either conflicts, omissions, or errors (Lutz et al., 1990). They are the leading cause of rework during projects (Love et al., 2010) and increased construction project costs. These defects represent 78% of the number of modifications, 9.5% of the global costs of the projects (Burati et al., 1992; Setiawan et al., 2019), 50% of the contract changes (Nigro, 1987), and 46% of contractual claims (Diekmann and Nelson, 1985). Business Week ("quality" 1982) stated that manufacturers claimed that 15–20% of the cost of their services were used to correct the errors. Moreover, according to these manufacturers, the best way to increase profits is to reduce the cost of poor quality rather than increase sales (Burati et al., 1992). Design flaws constitute the bulk of the administrative time reserved for projects, the origin of legal disputes, the dissatisfaction of customers, the reduction of worker safety, and motivation (Lutz et al., 1990).

According to Hughes et al. (2013), there are approximately 796 RFIs per project in the AEC industry, and it takes approximately 9 days to respond to an RFI. This corresponds to an average of 13,535 h-person per project. The cost to respond to a single RFI for a $1–10 million project can range from $598 to $2,078 (Sparksman, 2015).

The appropriate stage to improve the quality of construction projects is the design phase (Lawson, 2006; Crotty, 2012; Zhang et al., 2015). Between 6 and 23% of the original project cost estimate (Lutz et al., 1990), and 7% of the overall project cost (Nigro, 1987), can be reduced very early in projects by having designers working together with contractors. But, in a traditional project delivery method, this process is challenging and expensive to implement because it involves the presence of contractors during the design phase (Elvin, 2007). Besides, design and construction professionals are culturally different (Lawson, 2006). Involving them in the same stage of a project's life cycle can lead to endless arguments that will prolong the duration of the project and impinge on the quality of the final work (Kent and Becerik-Gerber, 2010).

Design reviews are a current practice to identify issues during the design process. They are considered operations to ensure the quality of contractual design documents (Lutz et al., 1990). The adoption of design reviews in the process may help to identify and reduce design errors. However, design reviews are hampered by the fact that they are often performed by designers and not by construction professionals. This can explain why design flaws remain in design documents despite design reviews (Lutz et al., 1990).

1.3 The use of RFIs to improve the quality of the design

RFIs are a reliable source to convey information. For Andrews (2005), RFIs are the conventional approach of communication between designers and contractors. They respond to a standard protocol that aims to make the information claim very useful. Each RFI corresponds to one and only one technical problem. The information needs and/or modification proposals in the RFIs are generally precise, clearly expressed, and signed by a professional who assumes the responsibility for the request. These characteristics of the RFIs are entirely part of the standard code of practices established by the American Institute of Steel Construction (AISC) and the Australian Institute of Steel Construction (AISC). These characteristics also give the RFIs high credibility as a source of information. We posit that these characteristics can be exploited to improve the quality of design phases and largely, all construction projects.

The use of RFIs to improve the quality of construction projects has already been the subject of some studies. Mohamed et al. (1999) and Papajohn et al. (2018) studied the factors that influence the response time of RFIs and their impacts throughout the projects. Burns (2007) studied RFIs to provide quantitative information on the relationship between selected RFI variables and performance in the shop floor production process. Burns (2007) also established a significant association between production performance of shop drawings and production performance in terms of cost and duration. Burns (2007) used a regression model to identify individual input variables of RFIs that largely influenced the predicted production performance of shop drawings. In an analysis of the causes, effects, and indicators of design defects, Tilley (1998) also proposed to quantify the causes of RFIs as a criterion for assessing design flaws in a construction project.

These studies show that RFIs can play a significant role in developing the quality of projects. To achieve this, one of the main steps is to develop a suitable methodology, which can extract from the analysis of RFIs—the knowledge necessary for the development of the design phase.

2 Methodology

This article presents a method to identify recurrent design flaws by analyzing the textual content of RFIs. The case study concerns an analysis of 18,408 RFIs from 26 projects (Table 1). The projects were started in 2006 and completed in 2018 by a single major steel manufacturing company in North America. These are the 26 most recent structural steel projects chosen because they were carried out by the same design team and by the same manufacturing team, in a design-bid-build type of contract. These projects are also selected because all of their RFIs were available.

Design flaws may vary depending on the complexity of the projects. The number of structural elements, the number of interactions between these elements, and the unpredictable combined effects between these elements can result in different problems during construction (Corning, 1998). For these reasons, this study proposes to divide the projects into three different groups. The classification is based on their tonnage. Thus, the small projects

Tab. 1: Set of parameters describing selected projects

Small projects (SP)	Codifications	*SP1*	*SP2*	*SP3*	*SP4*	*SP5*	*SP6*	*SP7*	*SP8*			Total
	RFIs quantities	124	47	42	78	105	32	289	111			*828*
	Response time (in days)	414	472	679	753	1,780	787	3,496	1,451			*9,832*
Medium projects (MP)	Codifications	*MP1*	*MP2*	*MP3*	*MP4*	*MP5*	*MP6*	*MP7*	*MP8*			
	RFIs quantities	192	191	457	202	581	324	198	224			*2,369*
	Response time (in days)	3,047	2,701	1,890	3,135	1,371	1,264	2,592	4,701			*20,701*
Large projects (LP)	Codifications	*LP1*	*LP2*	*LP3*	*LP4*	*LP5*	*LP6*	*LP7*	*LP8*	*LP9*	*LP10*	
	RFIs quantities	672	4,693	317	1,650	821	1,304	2,340	1,808	517	1,089	*15,211*
	Response time (in days)	62,128	297,230	14,448	38,321	8,125	7,968	42,348	11,672	8,970	17,384	*508,594*

are those that count from 0 to 999 tons of steel, medium projects from 1,000 to 4,999 tons of steel, and large projects from 5,000 to 30,000 tons of steel. The project parameters are shown in Table 1:

– 828 RFIs with 9,832 response time (in days) of RFIs for 8 small projects,
– 2,369 RFIs with 20,701 response time (in days) of RFIs for 8 medium-sized projects,
– 15,211 RFIs with 5,08,594 response time (in days) of RFIs for 10 large projects (see Table 1).

The response time (in days) corresponds to the number of days between the day of transmission of the RFIs and the day of its response. The day of issue of the RFIs is included in the count.

The RFIs for each of the project groups were extracted and prepared for the analysis.

To analyze these RFIs, two approaches were possible (Minichiello et al., 1990):

– the quantitative approach used to analyze fixed, measurable, and quantitatively comparable data and
– the qualitative approach concerned with understanding human behavior through data analysis based on the description of the themes and factors that characterize a situation.

The qualitative approach is chosen for this study because of the nature of the data (textual data) and the objective of the study, which concerns the identification of design flaws.

Ideally, the qualitative analysis of RFI text content should be carried out either by designers or by specialized contractors. This is because of their implication in the projects concerned by RFIs, and their use of a common language for their profession. However, RFIs are numerous in construction projects. Studying RFIs to extract factors that can improve the quality of design phases is humanly tricky. There is, therefore, a need to devise a method that relies on the automatic analysis of RFIs to extract the information essential to improve the quality of the design from a large dataset. One of the easily accessible tools for automatically analyzing text content is qualitative content analysis (QCA).

QCA is a research method that applies to textual data for human understanding (Downe-Wamboldt, 1992). This is one of the research methods used to analyze texts based on the characteristics of natural language, with particular attention to the meaning of textual content (Budd et al., 1967; Lindkvist, 1981; McTavish and Pirro, 1990; Tesch, 1990; Graneheim et al., 2017). QCA aims to classify knowledge and to understand the phenomena present in the texts through a subjective interpretation (Graneheim et al., 2017; Vaismoradi and Snelgrove, 2019). There are different typologies to characterize qualitative approaches. This study makes use of the typology proposed by Hsieh and Shannon (2005). They classified the approaches into three types: conventional, direct, and summative. The significant differences between these approaches are the origin of codes, the coding schemes, and the threat to reliability (Hsieh and Shannon, 2005). In the conventional approach, the coding categories are derived directly from the data of the text to be studied. In the direct approach, the analysis begins with a theory already established or based on research derived taxonomies. The summative approach involves counting and comparing (usually keywords or content), followed by the interpretation of the underlying context. Because the proposed method for this study aims to consider recurring problems by identifying keywords and interpreting their meaning, the summative approach seems the most suitable for the qualitative analysis of the RFIs.

The summative approach makes it possible to identify the main words present in the groups of RFIs. These words, which represent themes or codes, are then analyzed and compared. Finally, recommendations are formulated according to these themes. Figure 1 illustrates the workflow

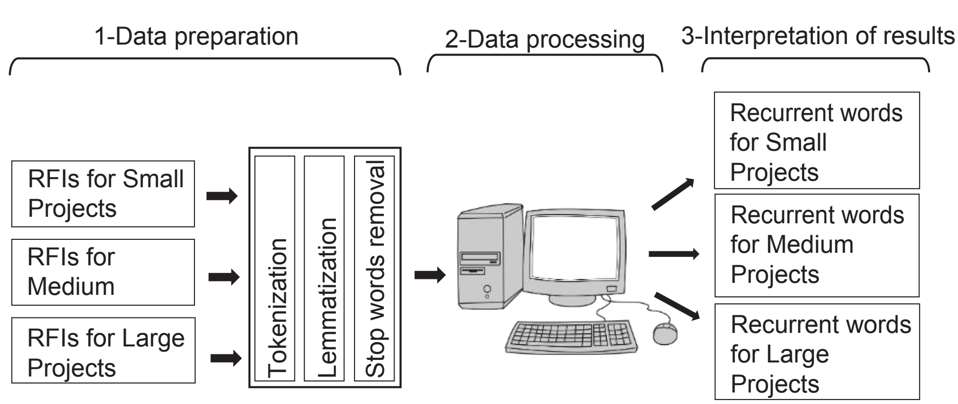

Fig. 1: The process to identify recurrent words in RFIs.

while the following sections provide more details on how the method was carried out.

2.1 Data preparation

The quality of a content analysis depends on the quality of the data at our disposal (Lantz, 2015; Thanaki, 2017). Thus, the first part of the method consists of finding all the RFIs contained in the previous projects selected for this article. Manual processing eliminates courtesy and civility formulations, surnames and names, and details that are not relevant information for a design document (Table 2). It is then necessary to adapt the data to the understanding of the machine (Han et al., 2011). This adaptation consists of tokenization, lemmatization, and stops word removal processes (Figure 1).

Tokenization is the process of splitting the flow of textual content into words, symbol terms, or other essential elements of understanding called tokens. The process of lemmatization or stemming is a method of representing words in ways that retain only their meaning. In this process, the nouns are converted to a singular masculine name, and the verbs are all converted to their infinitive form. Stop word removal is about simplifying the text by removing the words that do not have significant importance in communication (Vijayarani and Janani, 2016).

2.1.1 Data processing

This part consists of treating all the RFIs to identify the most frequent words and to classify them in a table (Mei and Zhai, 2005). These words are analyzed and defined as recurring themes in the content of RFIs. These themes represent the main design flaws facing contractors. To validate the results, this article proposes to quantify the RFIs that contain the most recurrent themes and to represent the response times of the RFIs that contain these themes. The obtained figures give an appreciation of the impact of each theme on a project. Three lists of the most recurrent words are created depending on the scope of the project.

2.1.2 Result presentation

The results are a list of words most presented in the RFIs and the corresponding response time for projects of different scales. The results also present the relationships that exist between the most frequent words.

i. Small projects

The small projects selected for the case study correspond to the structural construction of small businesses or offices building.

The most common words in the set of RFIs for small projects are given in Table 3.

The column "% of corresponding response time (days)" corresponds to the percentage impact of RFIs caused by each of these words or groups of words on the overall waiting time for RFIs.

Analysis and interpretation of RFI results for small projects are as follows:

- The words Provide, Connection, Confirm, and Beam are the most recurrent words in the set of RFIs.
- The word Provide or Confirm is presented in 39% of the RFIs. Also, the RFIs that contain the word Provide or Confirm cause 34% of response time before a response.
- The word Connection is also widely represented in the set of RFIs. It is presented in 17% of RFIs, and the RFIs that contain the word Connection cause 14% of response time.
- The word Connection is linked to the words Provide, Confirm, Line, Information, and Beam (Figure 2).
- Some words are found in several RFIs at the same time, which explains why the total number of percentages of words contained in RFIs may be higher than 100%.

The *bold squares* represent the most recurring words contained in the RFIs set (e.g., Connection), while the simple squares represent the moderately recurring words. The *bold arrows* indicate the most recurrent groups of words in the RFIs set (e.g., Confirm-Connection), while the arrows with dashed line represent the moderately recurring groups of words in the RFIs set.

Tab. 2: Example of how to group and classify RFIs

RFI_N°	RFIs	RFI_Issued_Date	RFI_Response_Date	Response_Time (in days)
1	Dimensions discrepancies between grids	16/02/2017	17/02/2017	1
2	Beam size discrepancy	16/02/2017	17/02/2017	1
...	...	...	...	...
N	Non-standard W beam size	16/02/2017	17/02/2017	1

Tab. 3: Words most frequent in the set of small project RFIs

Words	Frequency of words	Similar words	RFIs concerned (%)	Corresponding response time (%)
Provide	148	provide, provided	18	18
Connections	119	Connectant, connection, connections	17	14
Confirm	118	Confirm, confirmation, confirme, confirmed	20	16
Beam	110	Beam, beams	13	10
Detail	80	Detail, details	10	12
Location	72	Locate, location, locations	8	9
Dimension	69	Dimension, dimensions	8	9
Plate	67	Plate, plates	9	8
Missing	62	Missing	6	9
Column	60	Column, columns	8	7
Elevation	51	Elevation, elevator	7	9
Roof	51	Roof	4	8
Complexe	45	Complexe	5	4
Provide or confirm	266		38	34

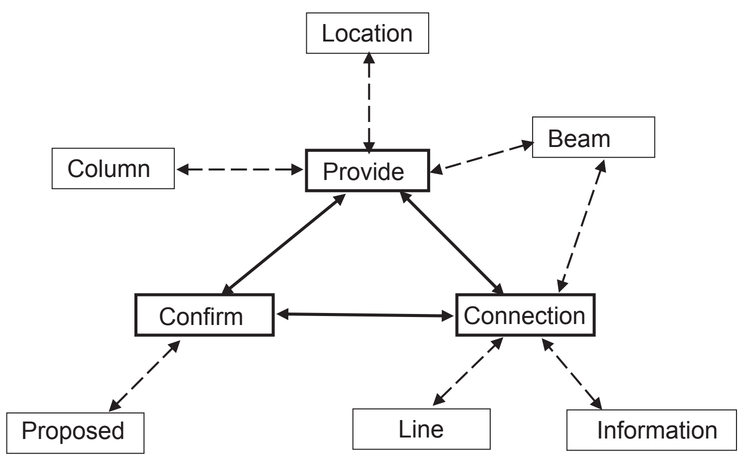

Fig. 2: Relationships between the three most frequent words in the RFIs of small projects and the other recurrent words.

From the above, we can state that the analysis of the textual content of the RFIs of small projects can allow the identification of two main recurring problems present in the design documents:

– The need for contractors to obtain additional information regarding localization, beams, columns, and connections.
– The need for contractors to obtain more information related to the connections.

ii. Medium projects

The medium projects selected for the case study concern the construction of large buildings for retail or development and the extension of sports centers and leisure areas.

The most frequent words in the set of RFIs for medium projects are given in Table 4.

Analysis and interpretation of the results relating to the RFIs of the medium projects are as follows:

– The words Provide, Confirms, Connection, and Beam are the most common in RFIs.
– The word Confirm or Provide corresponds to 56% of RFIs medium projects. Also, the RFIs of medium projects that contain the word Confirm or Provide cause 45% of response time before a response.
– Like for small projects, the word Connection is also widely represented. It is presented in 21% of RFIs and causes 17% of response time.
– The word Connection is linked to the words Confirm, Provide, Module, and Beam (Figure 3).

From the above, we can affirm that the analysis of the textual content of the RFIs of medium projects, such as the

Tab. 4: Words most present in the set of medium projects RFIs

Words	Frequency of words	Similar words	RFIs concerned (%)	Corresponding response time (%)
Confirm	897	Confirm, confirmation, confirmed, confirmer	38	20
Connections	499	Connect, connectant, connected, connection, connections	21	17
Provide	440	Provide, provided	19	25
Beam	261	Beam, beams	9	9
Sketches	245	Sketch, sketched, sketches	10	3
Dimension	192	Dimension, dimensions	8	12
Column	190	Column, columns	8	9
Location	178	Locate, located, locating, location, locational, locations	8	13
Detail	137	Detail, detailed, detailing, details	6	10
Plate	134	Plate, plates	6	5
Lines	128	Line, lines	6	4
Stair	121	Stair, stair#1, stair#2, stair#7, stairs	5	10
Grids	117	Grid, grids	5	4
Elevator	114	Elev, elevation, elevations, elevator, elevators	4	7
Brace	110	Brace, braced, braces, bracing, bracings	3	2
Confirm or provide	1337		57	45

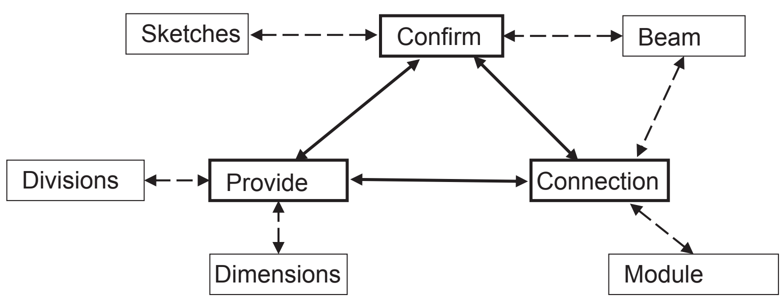

Fig. 3: Relationships between the three most frequent words in the RFIs of medium projects and the other recurrent words.

analysis of small projects, can allow the identification of recurring problems in design documents such as:

– the need for contractors to obtain additional information related to dimensions, location (represented here by "division"), beam, and sketches and
– the need for contractors to receive more information about connections;

iii. Large projects

The large projects selected for this study are those related to the construction of shopping centers, stadiums, and large buildings.

2.1.3 Frequency of words and themes

The most common words in the set of RFIs for large projects are given in Table 5.

Analysis and interpretation of the results relating to the RFIs of the large projects are as follows.

– The words Clarify, Confirm, Connection, and Level are the most recurrent in the set of RFIs for large projects.
– The words Provide and Confirm are presented in 26% of the RFIs. The RFIs that contain these words cause 12% of the response time of the RFIs of the large projects.
– The word Connection is also widely represented. The word Connection is contained in 15% of the RFIs. Also, the RFIs that contain this word cause 10% of the response time. The word Connection is linked to the words Confirm, Provide, and Level (Figure 4).

From the above, we can affirm that, such as for small and medium projects, the analysis of the textual content of the RFIs of large projects can allow the identification of

Tab. 5: The words most present in the set of RFIs for large projects

Words	Frequency of words	Similar words	RFIs concerned (%)	Corresponding response time (%)
Confirm	2,383	Confirm, confirmation, confirmations, confirmed	16	7
Connections	2,325	Connect, connected, connecting, connection, connections	15	10
Clarify	2,305	Clarifie, clarified, clarify	4	4
Levels	2,214	Level, levels	14	18
Layout	1,818	Layout, layouts	12	15
Beams	1,592	Beam, beam@, beams	10	4
Provide	1,549	Provide, provided, provides, providing	10	5
Detail	1,121	Detail, detailed, detailing, details	7	5
Zones	978	Zone, zones	6	18
Elevator	802	Elev, elevation, elevation@, elevations, elevator, elevators	5	5
Dimensions	799	Dimension, dimension@, dimensions	5	2
Missing	792	Missed, missing	5	3
Plates	751	Plate, plate@, plated, plates	5	1
Lines	739	Line, lines	5	3
Confirm or provide	3,932		26	12

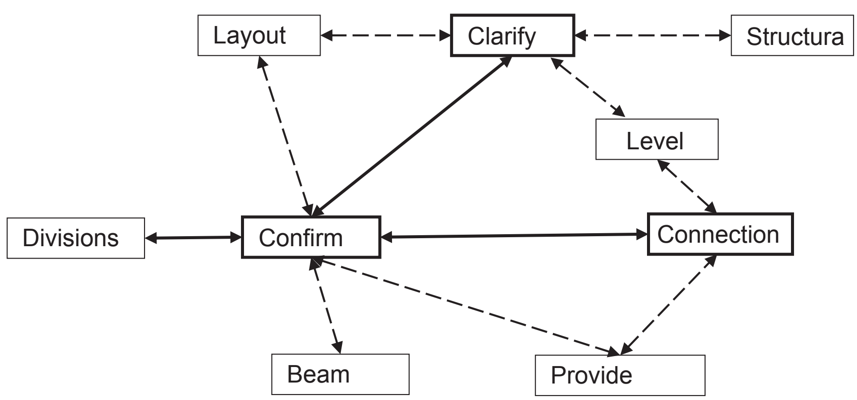

Fig. 4: Links between the three most frequent words in the RFIs of large projects.

recurring problems in the design documents. In the case of this study, we have:

- the need for additional information related to the location (represented here by "level" or "division"), sketches (represented here by "layout"), and beam and
- the need for specific information relating to connections.

The word Connection seems to refer to a large number of RFIs. The study proposes a representation of the impact of the word "connection" per project on RFIs, and on the response times related to the RFIs that contain this word (see Table 6).

With 0.06, 1.52, and 3.13%, LP2 MP7 and SP6 projects are projects where the word Connection is very rarely used in RFIs. Also, the RFIs of these projects that contain the word Connection represent 0.23, 0.23, and 7.5% of the response times for RFIs for these projects, respectively. The reasons given by the professionals involved in these projects are that the LP2 and MP7 projects concern the construction directly related to public transport. The SP6 project concerns the rehabilitation of a hotel building. These three projects did not involve the use of several connections.

Otherwise, in general, 17% of RFIs in small projects, 21% of RFIs in medium projects, and 15% RFIs in large projects contain the word Connection. The RFIs that contain this word cause 14, 17, and 10% of the response times of the RFIs of these projects, respectively.

Tab. 6: The impact of the word Connection on the RFIs studied

	Codifications	RFIs quantities	RFIs (Qty) with connection	RFIs (Qty) with connection (%)	Average of RFIs with connection (%)	Standard deviation	Response time (in days)	Waiting days for RFIs with connection	Waiting days of RFIs with connection (%)	Average of waiting days of RFIs with Connection	Standard deviation
Large projects	LP1	672	75	11.16	15	0.11	62,128	11,885	19.13	10%	0.16
	LP2	4,693	3	0.06			297,230	683	0.23		
	LP3	317	61	19.24			14,448	5,551	38.42		
	LP4	1,650	462	28.00			38,321	16,177	42.21		
	LP5	821	138	16.81			8,125	247	3.04		
	LP6	1,304	426	32.67			7,968	2,799	35.13		
	LP7	2,340	659	28.16			42,348	10,089	23.82		
	LP8	1,808	378	20.91			11,672	1,256	10.76		
	LP9	517	28	5.42			8,970	158	1.76		
	LP10	1,089	110	10.10			17,384	1,874	10.78		
		15,211	2340				508,594	50,719	10.78		
Medium projects	MP1	192	40	20.83	21	0.12	3,047	443	14.54	17%	0.13
	MP2	191	29	15.18			2,701	385	14.25		
	MP3	457	58	12.69			1,890	218	11.53		
	MP4	202	58	28.71			3,135	1,109	35.37		
	MP5	581	239	41.14			1,371	520	37.93		
	MP6	324	32	9.88			1,264	77	6.09		
	MP7	198	3	1.52			2,592	6	0.23		
	MP8	224	44	19.64			4,701	733	15.59		
		2,369	503				20,701	3,491			
Small projects	SP1	124	29	23.39	17	0.07	414	87	21.01	14%	0.07
	SP2	47	7	14.89			472	20	4.24		
	SP3	42	6	14.29			679	109	16.05		
	SP4	78	6	7.69			753	119	15.80		
	SP5	105	11	10.48			1,780	85	4.78		
	SP6	32	1	3.13			787	59	7.50		
	SP7	289	64	22.15			3,496	724	20.71		
	SP8	111	14	12.61			1,451	167	11.51		
		828	138				9,832	1,370			

3 Discussions

In general, this article shows the following characteristics for steel construction projects:

- A summative qualitative analysis of RFI content can identify the most recurrent design flaws that hinder the contractor's work.
- This analysis can also propose the quantity of RFIs, and the corresponding response time related to the recurring themes identified.
- The identification of these flaws can promote initiatives that aim to reduce the quantity of RFIs, the response time of RFIs, and improve the quality of design documents for future projects.
- This analysis can also promote the formulation of design information in a way that is adapted to the needs of contractors.
- The use of building information modeling (BIM) technology can ensure better communication between designers and contractors (Zou et al., 2017). Using BIM may ideally allow the contractor requirements to be taken into account in the BIModel during the design phase.

In the specific case of the case study:

- The recurring words in the RFIs of the selected projects do not change much according to the size of the projects, as seen in Tables 3–5.
- The words Provide, Confirm, and Clarify directly related to information needs. This may justify the primary defect in the design of steel structures in the design office, which is the absence or misrepresentation of information in design documents.
- The words Provide, Confirm, and Clarify are linked to the words Beam (or columns) and Location (division or level) for all types of projects. In our opinion, this highlights systematic errors while producing and providing information on the location and description of steel structural elements during the design phase of steel projects. The words "Provide" and "Confirm" are mainly related to the word Proposed in the small projects of steel construction. This can justify the presence of numerous proposals made by the contractors to the design teams on the design of the structural elements of the small steel construction projects.
- The word Connection is really represented in RFIs in a general way. This may reflect the fact that there is a real problem with how connections are designed and communicated to contractors.
- The word Connection is also linked to the words Beam and Column (structural). The word Connections in the steel construction industry is used to connect beams and columns. Linking these words with the word Connection may justify the absence of the essential information required for the connection from the beams and columns.
- Also, some projects have more than 20% of the response time (in days) caused by RFIs that contain the word Connection (see Table 6). It may be interesting to look with the concerned parties to discover the particularity of these projects. This analysis may give an idea of the types of projects that cause a long period of response time.

Structural steel designers participating in this case study suspected that connection design was the source of many RFIs received over the years. The method confirms the suspicion and can quantify this phenomenon, both in terms of frequency of occurrence and time delay.

The case study helps to identify recurring problems in the RFIs of small, medium, and large projects. In general, the issues are related to the lack of information related to structural elements, their positions in space, and the way connections are designed. The manufacturer has already taken corrective measures. Time will tell if taking them into account will help to improve the quality of the design documents for a future small, medium, and large projects. An analysis of the textual content of the RFIs of future projects will provide information on the effectiveness of these measures.

This method can also be applied to other professions in the construction industry, which are affected by fragmented processes. This will require a coordinated RFIs process that respects the standards given by AISC. It will also require sets of RFIs from previous projects, written by the same contractor teams, and intended for the same designers teams. If these conditions are not met, the recurrent problems contained in the RFIs may vary significantly from one project to another, and the estimation of their impact may be uncertain.

4 Conclusion

This article proposes to improve the quality of steel construction projects through a systematic method, which applies a qualitative analysis on RFIs text content, to identify the most recurrent information needs, formulated by contractors toward designers. RFIs are highly structured textual data sources that contain the needs of contractors to designers. The particularity of this study is that this article uses a qualitative summative method using QCA software rather than an investigation between designers and contractors. The use of the software here is simply due to the large quantity of RFIs usually present in projects in the AEC industry. A case study presented in this article shows the feasibility of this method in steel construction projects. In terms of results, this article shows that RFIs are rich in useful quality information, and that, RFIs can be used to improve the quality of the project design phase in the AEC industry. This article also indicates that it is possible to extract recurring problems from design documents. The results of the case study developed in this article indicate that the recurring issues contained in RFIs do not depend on the size of the projects. These problems also reflect the need to improve the way connection information is formulated. This article has reinforced suspicions and prompted initiatives on the part of the professionals of the company concerned by the case study. In perspective, this study proposes to take into account the information needs expressed in the case study in an ongoing project and to assess the impact of these recommendations.

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