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FRAMEWORK FOR MEASURING PROCESS INTEROPERABILITY IN CONSTRUCTION MANAGEMENT

Kang, Seokyoung[1], Haas, Carl T.[2,4] and Golzarpoor, Behrooz[3]
[1, 2, 3] University of Waterloo, Canada
[4] chaas@uwaterloo.ca

Abstract: Organizations are required to collaborate in capital projects. While each organization has its own role and responsibility for a project, process interoperability between these organizations is necessary to deliver successful projects. However, compared to discussions on general enterprise interoperability, process interoperability in construction management is in its early stage. This is because enterprise interoperability has broader meaning than process interoperability in most industries. On the other hand, capital projects emphasize processes that connect multiple enterprises involved in a project. In this paper, process interoperability in construction management is defined as management-level workflow connection between organizations in a construction sector. In order to improve process interoperability in the construction field, a prior step would be to develop a framework for measurement of process interoperability. Thus, this study proposes a foundation for measuring process interoperability in the construction management field. The measuring method consists of three levels: project, organizations and execution-level. These approaches are explained in the paper, and examples using case studies are presented for initial validation. This methodology avoids self-reported and subjective responses on questionnaires. Moreover, this method can be used for consulting to understand the status of projects, organizations, and processes in terms of process interoperability.

1 INTRODUCTION

In general, interoperability is achieved when products or systems can access or implement interfaces without any restrictions. A USB that can be connected to a computer is an example of interoperability. The computer can not only access the USB but also exchange and/or modify data. The World Wide Web is another example of a medium that allows exchanging information without restrictions. Nowadays, with cloud systems, storing and exchanging data via the web have become simple and straightforward. Likewise, the term ‘interoperability’ originated from information technology or systems engineering (IEEE 1990).

Interoperability can also be defined differently in diverse fields. For instance, in healthcare, interoperability is defined as “the ability of different information technology systems and software applications to communicate, exchange data, and use of information that has been exchanged” (HIMSS 2010). This is crucial for healthcare services to reduce unnecessary waiting time or the cost of re-examinations. E-government needs to deal with challenges due to different languages, specifications of formats, and legal conditions. Interoperability is also important in public safety and military/police forces due to the communication required during wide-scale emergencies. By advocating interoperability, the government can ensure that citizens gain safety and better services. Interoperability also allows open market and free competition.

Enterprise interoperability, the ability of interaction between enterprises (Chen 2006), consists of four levels: data, process, service, and business interoperability (Chen 2006). There have been approaches to uncover these concepts and to analyze them. However, process interoperability as an independent concept, specifically in the construction management field has been neglected. What is often not considered is that a project unit is a broader concept than an enterprise unit in a capital project as every project is independent from each other and consists of different enterprises. Process interoperability, which can be defined as a workflow connection between organizations, serves a vital role in capital projects where processes are intertwined among organizations. While it is not a sufficient condition, process interoperability is required to deliver a successful project.

However, there is no common measurement tool available to simply and intuitively measure process interoperability. Although there are performance assessment tools which interoperability can sometimes be merged into, current methods do not clearly and objectively measure it. The approach this paper takes differs from existing self-reporting survey questionnaires. It is designed for a consultant who is a third-party from the project to analyze its current status. Also, the main purpose of this measurement is not external evaluation. It is to internally measure and evaluate the current status of the project. If process interoperable points are found earlier in a project, it will reduce resources needed to solve problems. The measuring tool suggested in this study introduces a broad concept but narrows down and finally provides quantitative results bottom-up.

2 LITERATURE REVIEW

There have been more than 60 definitions of interoperability; however, there is as yet no broadly accepted, precise and fixed definition (Gibbons et al. 2007). (NAHIT 2005, Gibbons et al. 2007) defined interoperability as “the ability of different information technology systems and software applications to communicate, to exchange data accurately, effectively, and consistently, and to use the information that has been exchanged.” (Gibbons et al. 2007) defined interoperability as “the capability for two or more systems to exchange information and to use reciprocally their functionality.”

(Gibbons et al. 2007) identified three principal levels of interoperability: technical, semantic, and process interoperability. Technical interoperability refers to data exchange among systems; semantic interoperability refers to meaningful data exchange; and organizational or process interoperability refers to collaboration of work processes through multi-organizational business processes participation (Gibbons et al. 2007, Golzarpoor 2016). The European Telecommunications Standards Institute (ETSI) has recently introduced a syntactic level (Khan et al. 2013, Kubicek et al. 2009).

(Golzarpoor 2016, Kubicek et al. 2009, Veer et al. 2008) describe process interoperability as embracing semantic and data interoperability. Process interoperability ensures communication between different systems by sharing processes (Khan et al. 2013). (Golzarpoor 2016) defines process interoperability as “the interaction and collaboration of workflow processes between different organizations.”

While the concept of interoperability has been comprehensively explored, measurement requires more discussion. According to (Chen et al. 2008, Ducq et al.2008), interoperability can be measured by removing barriers: conceptual, technological, and organizational. Conceptual barriers include syntactic and semantic; organizational barriers include persons and organizations; technological barriers include platform and communication (Chen et al. 2008, Ducq et al.2008). Once the terms were defined, the measurement matrix and equations were developed in terms of time, cost, and quality of interoperation. The methodology is logical; however, it is more theoretical than realistic as time, cost, and quality used for measuring have different units and they are not easy to measure. Furthermore, whereas previous approaches are based on enterprise interoperability, this study investigates the process interoperability of capital projects.

3 METHODOLOGY

The final goal of this study is to build a framework that can provide a quantitative figure which represents a project's overall process interoperability. Process interoperability emerges when two organizations start collaborating and interacting in their workflows. Their workflows influence or interfere with each other. This paper uses a bottom-up method to measure process interoperability on workflows. However, for the sake of understanding, the paper proceeds in a top-down way from project-level, organizations-level, to execution-level. Figure 1 illustrates calculation sequence and organization of this paper.

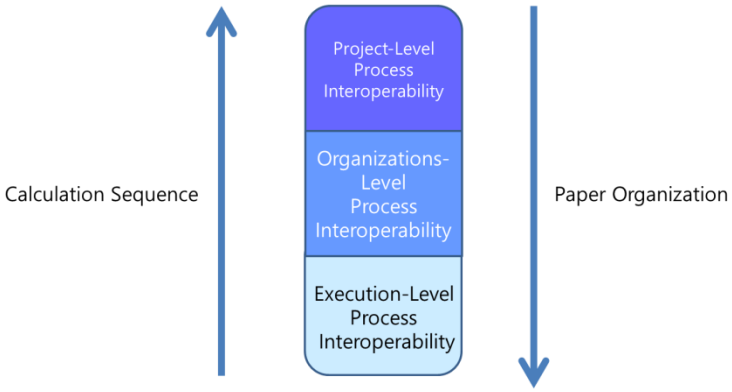

Figure 1: Overall methodology for measuring project processes interoperability

3.1 Project-Level Process Interoperability

Capital projects involve stakeholders from various organizations. For simplicity, their relationship can be illustrated such as Figure 2. The circles represent organizations, and the thicknesses of lines between the circles indicate the degree of process interoperability. Considering all the lines connected to organizations, project process interoperability can be derived. While a project process interoperability index can be derived from simple equations, such as sum or average, to more complicated forms by adding variables and parameters, they are not the scope of this study.

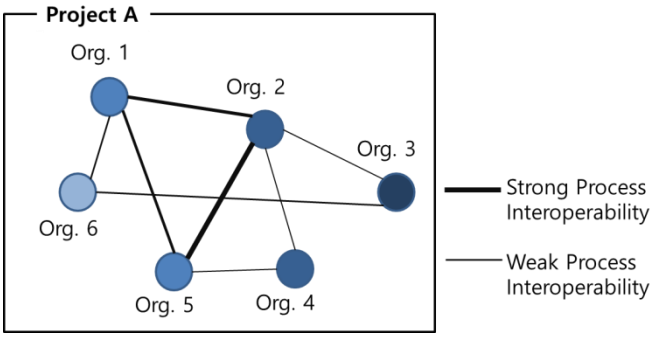

Figure 2: Diagram for project-level process interoperability

3.2 Organizations-level Process Interoperability

Stakeholders include owners, contractors, subcontractors, and suppliers. Organization charts can also vary according to contracts and partnerships. For example, a joint venture (JV) is a common partnership in capital projects to share risk and reward. An example of a capital project organization chart is shown in Figure 3. Note that there are vertical as well as horizontal hierarchies among stakeholders.

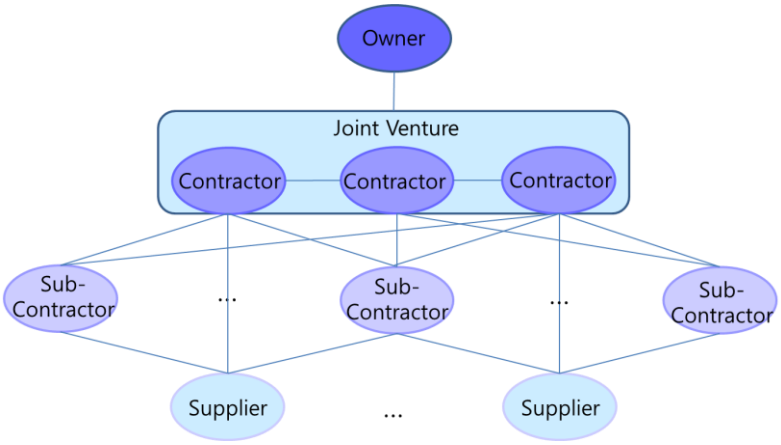

Figure 3: An example of capital project organization chart (Joint Venture)

Organizations-level process interoperability considers all possible forms of process interoperability between organizations. Figure 4 presents further descriptions. While there are some internal processes within organizations such as Process B and Process D, there also exist workflow processes that are connected to each other such as Process A1-A2 and Process C1-C2. While the former collaboration within an organization is called integration, the latter connection between organizations is called interoperability (Chen et al. 2008). Process interoperability between processes can be very strong, very weak, or somewhere in between. The goal of this stage is to derive a quantitative figure that represents organizations-level process interoperability. Specific calculation is beyond the scope of this study.

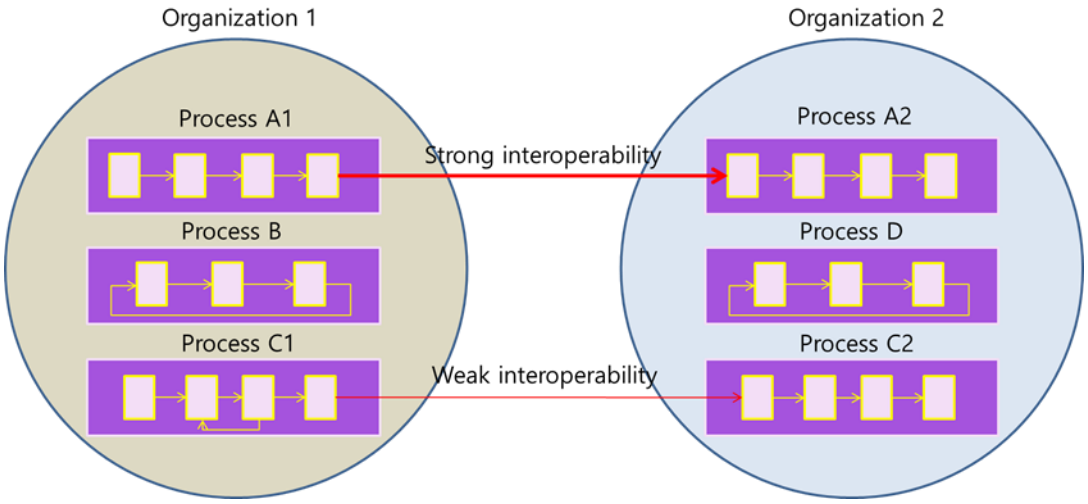

Figure 4: Systems diagram for organizations-level process interoperability

3.3 Execution-level Process Interoperability

Execution-level process interoperability is the main stage for measuring process interoperability. In Figure 4, notice Process A1-A2 has strong process interoperability while Process C1-C2 has weak interoperability. In this level, each interoperable process is analyzed and evaluated to derive a quantitative figure for execution-level process interoperability.

To do so, there are three main steps. First, consistent processes or workflows have to exist for two organizations. Then, the interoperating processes should be illustrated in a simple diagram that demonstrates the interoperable points or boundaries clearly. This is further explained in case studies with Figures 6 - 7.

Next, data needs to be checked. Data refers to the kinds of software and syntax (data structure) the organizations are using, which could be same or compatible. Manual processes, inconsistent formats, and multiple non standardized tools create incompatibility. By finding incompatible points, interoperability can be calculated reversely. Figures 8 - 10 illustrate some examples for data interoperability.

Finally, corporate documents or information that are sent from one organization to another should be evaluated in terms of semantics. Documents should include mutually exclusive, collectively exhaustive contents which are consistent and coherent. If some information is missing, repetitive or incoherent, it is considered noncompliant. For noncompliance, the process interoperability will turn out to be weaker. This concept is also explained in case studies with Figures 11 - 12.

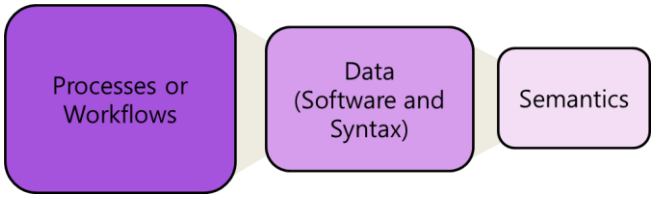

Figure 5: Procedure of measuring execution-level process interoperability

4 CASE STUDIES

4.1 First step: Illustration of Processes

The first step is to find interoperable points or boundaries in processes or workflows. To do so, processes can be extracted from practices. Figure 6 is an example of interoperation between two organizations. Notice there is an external approver involved for the change request (CR) process. In this process, interoperable points are apparent between Organization B and Organization A's approver, coordinator and initiator.

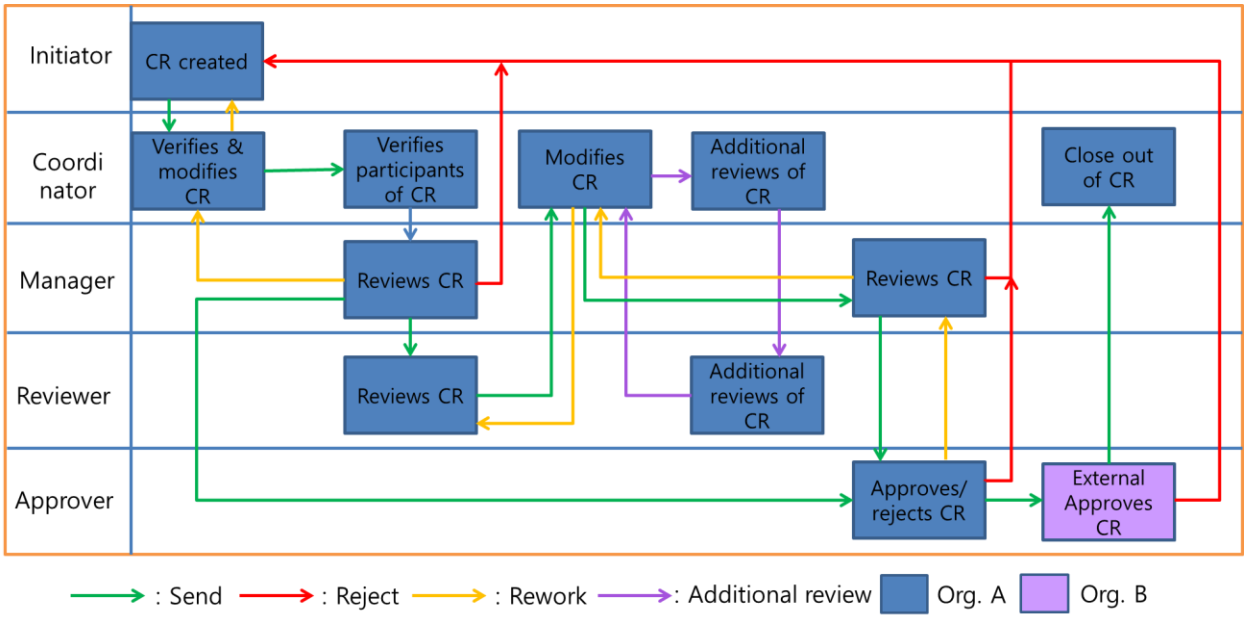

Figure 6: An example of workflow: change request (CR) process with two organizations

Figure 7 is another example of process for field device implementation. This process is even more evident as it includes different organizations' roles. Red arrows indicate process interoperability between different organizations. The second step further discusses how these interoperable points are used.

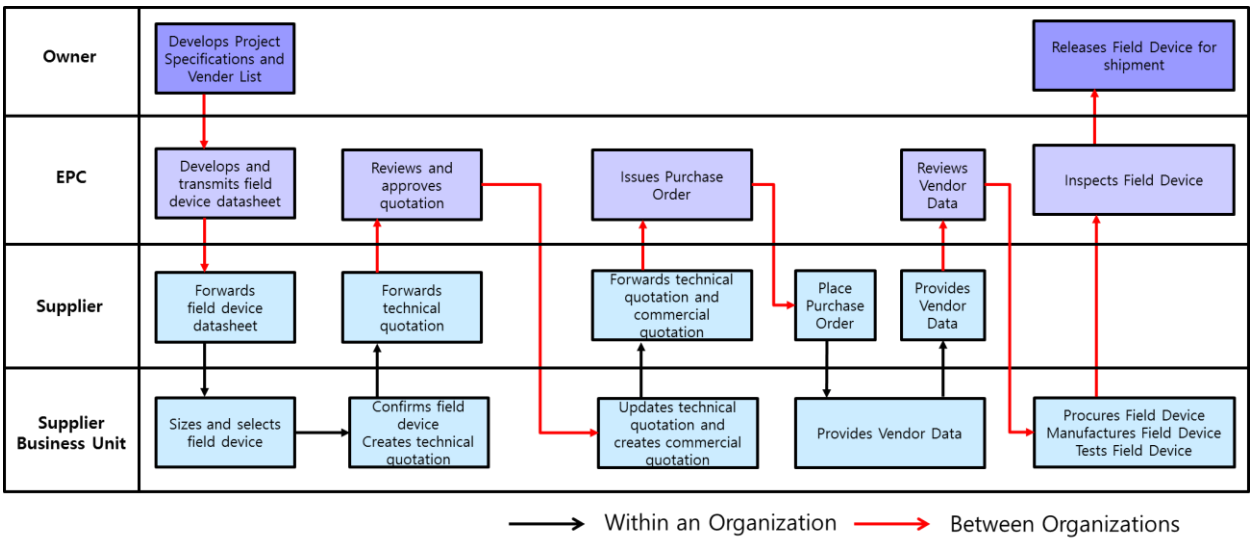

Figure 7: An example of workflow: field device implementation process with four organizations

4.2 Second step: Compatibility of Data

Data compatibility should be examined at each interoperable point that is found. Notice the red arrow from Supplier to EPC in Figure 7. Figure 8 is an example of metadata of a document from a supplier. Information is entered in a spreadsheet such as Excel. Then, this metadata can be transformed into Figure 9, document profile window of EPC. Figures 8 - 9 include the same data in different formats.

	Transmittal #	M4123453			**Request ID**	TRANS-0001
	Vendor Contract #	200110			**Issue Date**	07/14/2015
	Originator	PAU			**Recipient**	GAN
	From	Paul			**To**	Gagan
	Remarks	Please review			**Project**	519781
File Name (M)	**Issuers Document ID (O)**	**Document ID (M)**	**Document Title (M)**	**Revision Number (M)**	**Document Status (M)**	**Issue Purpose (M)**
FDI-10-0101.pdf	PAU100010	519781-FDI-DCL-0083	0083	R49	SUB	REV

Figure 8: An example of metadata of a document: spreadsheet from a supplier

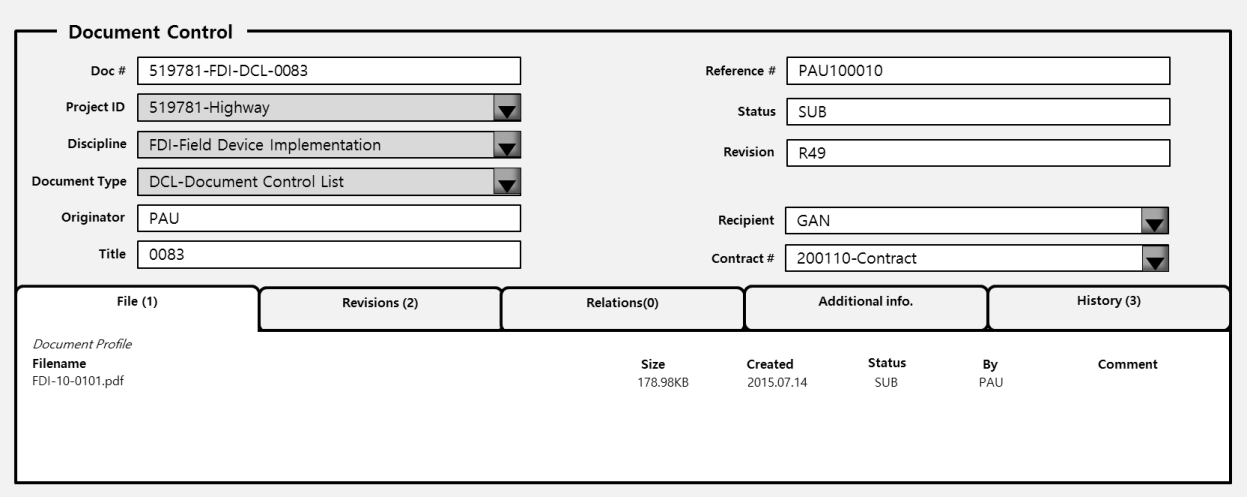

Figure 9: An example of metadata of a document: document profile window from an EPC

To translate Figure 8 to Figure 9, data should be extracted, transformed and loaded into proper format. Table 1 analyzes different data structures (syntax) of Figures 8 - 9.

Table 1: Comparison between different data structures

Figure 8		Figure 9		Comments
Originator	PAU	Originator	PAU	Same
Recipient	GAN	Recipient	GAN	
File Name	FDI-10-0101.pdf	Filename	FDI-10-0101.pdf	Matching
Issuers Document ID	PAU10010	Reference ID	PAU10010	
Document Title	0083	Title	0083	
Revision Number	R49	Revision	R49	
Document Status	SUB	Status	SUB	
Vendor Contract #	200110	Contract #	200110-Contract	Different Format
Issue Date	07/14/2015	Created	2015.07.14	
Project	519781	Project ID	519781-Highway	
Transmittal #	M4123453	-	-	Missing
Request ID	TRANS-0001	-	-	
From	Paul	-	-	
To	Gagan	-	-	
Remarks	Please review	-	-	
Issue Purpose	REV	-	-	
Document ID	519781-FDI-DCL-0083	Discipline	FDI-Field Device Implementation	Different Configura-tion
		Document Type	DCL-Document Control List	

Table 1 conveys different cases: same, matching, different format, missing, and different configuration. The same refers to cases where both labels and values are the same. Matching refers to different labels but the same values. There are different formats for values, and some labels and values are missing. Different configurations combine values from other fields.

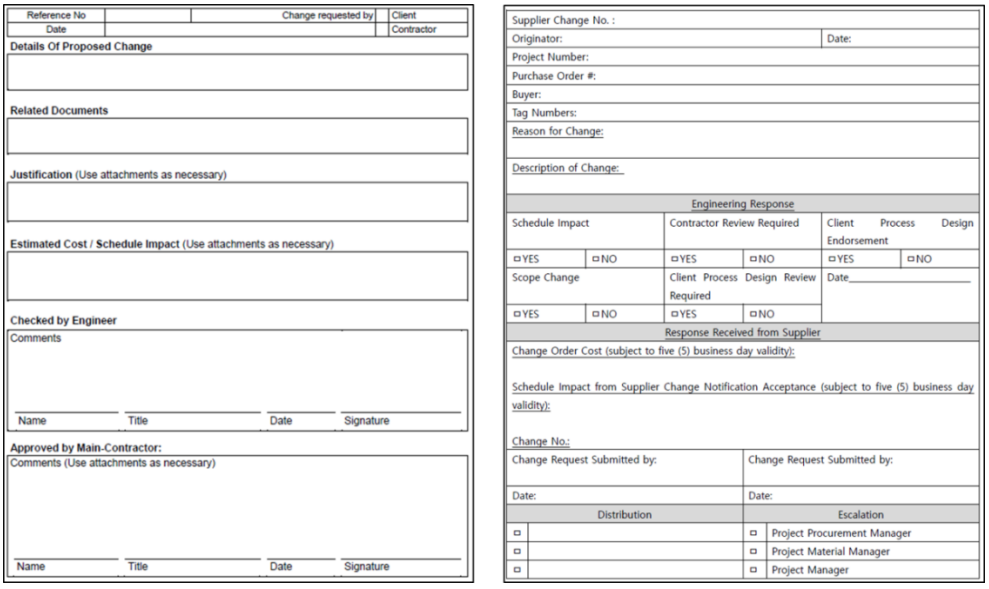

Figure 10: An example of document formats (left: Client/Contractor, right: Supplier)

Another example is presented in Figure 10. The formats of the two documents of change request are different. Not only because requests are designed by and targeted to different stakeholders but also because they are in different forms, readers need time to translate the documents. In order to be compatible and to be read easily by all stakeholders, unification of formats and syntax is suggested.

Table 2: Comparison between document formats

Left (Figure 9)	Right (Figure 10)	Comments
Reference No.	Supplier Change No.	Matching
Change requested by	Originator	
Details Of Proposed Change	Description of Change	
Justification	Reason for Change	
Estimated Cost / Schedule Impact	Engineering Response	Different Format
Comments Checked by Engineer		
Comments Approved by Main-Contractor	Response Received from Supplier	
-	Scope Change	Missing
-	Client Process Design Endorsement	
-	Client Process Design Review Required	
-	Project Number	
-	Purchase Order #	
-	Buyer	
-	Tag Numbers	

Table 2 conveys different cases: matching, different format and missing. Matching refers to different labels but expecting similar types of values. Different format refers to the difference in structure such as yes or no versus short-answer questions. If either one lacks information from the other, it is regarded as missing.

4.3 Third step: Compliance of Corporate Documents

Finally, transmitted corporate documents need to be examined. Examples of corporate documents are presented in Figures 11 - 12.

REQUEST FOR INFORMATION

RFI No	SC/RFI/012	Date	2016.02.14	Reference	
Subcontractor's Name	Subcontractor Construction Co., Ltd			Contract	Article 3.2
Subcontract Work	Earth work (Bored Piling)			BOQ	2.2.1
Reply required date	2016. 02. 18 (4 days)			Specification	Part 4 Volume 2
Attachments	Part copy of drawing TD/20403-001(B)			Drawing	TD/20403-001 rev.B
	Specification Part 4 Volume 2 (4.2)			Others	

Information Required :

Discrepancy of main steel bar of bored pile BP1

1. Main reinforcement steel bar of bored pile type BP1 is 24T36 according to drawing TD/20403-001(B).
2. 32T36 is shown on specification Part 4 Volume 2 [Specification for Bored Piling] article 4.2.
3. Our schedule of starting fabrication of steel cage is Feb. 19.
4. Please clarify this discrepancy and provide us with information by Feb. 18.

Submitted by:

[SIGN] name : Subcon manager — Name and Signature

2016. 02. 14 — Date

Received by:

[SIGN] name : Contractor Staff — Name and Signature

2016. 02. 14 — Date

Figure 11: An example of corporate document: request for information (RFI)

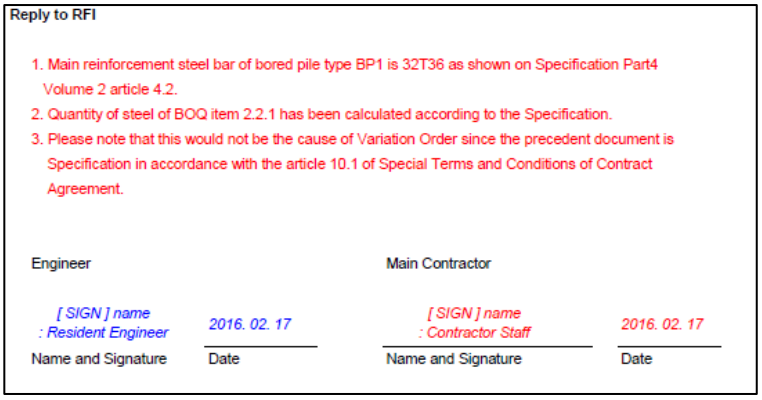

Figure 12: An example of corporate document: reply to RFI

These two documents of RFI (Request for Information) and reply for RFI are noncompliant for three reasons. First of all, while the RFI separated request 1 and 2, the reply merged responses and came up with response 1. Also, response 2 was an answer to a non-asked question, as the request did not require any information about quantity. Moreover, response 3 had an ambiguous reference such as 'this.' Such unclear semantics can cause confusion and delays.

5 CONCLUSION

This paper has introduced process interoperability in construction management by defining and suggesting a framework for measuring it with examples and case studies. Process interoperability in construction management is defined as management-level workflow connection between organizations in construction. Process interoperability can be measured by illustrating processes, checking data compatibility, and semantic compliance. Process illustration makes it easier to find interoperable points or boundaries where information is exchanged. Data compatibility refers to compatibility between different data or formats. Semantic compliance refers to the compliance between different terms in documents. This paper has limitations. For example, it only considers criteria that could be quantitatively measured omitting cultural or language barriers. However, a framework demonstrated can simply and objectively measure process interoperability. For future studies, detailed algorithms will be developed with proper variables and parameters. Validation through multiple case studies will also be completed.

Acknowledgements

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