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INDUSTRY FOUNDATION PROCESSES (IFP) – A UNIQUE APPROACH TO IMPROVE PROCESS CONFORMANCE AND INTEROPERABILITY

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Abstract: Process conformance and interoperability are long sought after goals in capital facility engineering and construction project management. Processes are defined within corporate operating standards by the most sophisticated firms, but research studies confirm that they are not implemented consistently from project to project. It is well established from statistical analysis of hundreds of projects that improved process conformance and improved interoperability are correlated with substantial improvements in project performance in terms of cost, schedule, and productivity.
Process conformance in many industry sectors such as health care, manufacturing, and banking has been radically improved with automation and integration of processes via workflow engines. In the construction industry, data interoperability has substantially been improved over the years with employment of data modeling techniques and standards. Process interoperability which enables inter-organizational communication between project stakeholders in large-scale construction projects is relatively less developed.
This paper introduces the concept of Industry Foundation Processes (IFP), and discusses its development and applications. IFP is a unique process modeling system that facilitates integration of core processes of known best practices in the construction industry into workflow management systems, and improves process conformance and interoperability. IFP processes are defined as structured workflow processes based on known best practices in the construction industry, with specific features and properties that comprise the IFP ontology: version, scope, core structure, abstraction level, data structures, recommended practices, workflow inheritance, conformance, and interoperability.
In addition, this paper offers an implementation framework for the IFP system, and describes how IFP processes can be customized to more detailed processes suitable to particular types of projects, and then to specific projects, and how the IFP ontology facilitates improved process conformance and interoperability in the domain of the construction industry.

1 Introduction

Today's large-scale construction projects are almost entirely managed by sets of workflow processes that are carefully designed to control different aspects of the project. The workflow processes are enacted by workflow engines of sophisticated process-aware information systems that facilitate communication and collaboration of project stakeholders using cloud computing services. In oil-and-gas, mining, and energy sectors, for example, such state-of-the-art information systems are typically comprised of a workflow management system, a document management system, and a collaboration management system; and they offer several services, such as product data management, project controls, project change management, project risk management, and more recently project interface management.

As a result, processes play a vital role in the success of projects, and process conformance and process interoperability are becoming increasingly important for more effective and efficient management of large-scale projects (Lipman, Palmer, and Palacios 2011). Process conformance to industry best practices, regulatory and contractual obligations, organizational policies, and service level agreements are associated with substantial improvements in performance and productivity (Golzarpoor, Haas, and Rayside 2016; Rohloff 2011). Moreover, process interoperability facilitates more effective communication and exchange of information among project information systems, and is an important measure of organizational alignment. Process conformance and interoperability have been significantly improved in particular domains, such as healthcare, banking, and military via employment of process models, workflow engines, and the latest information technologies (Brailer 2005; Khan et al. 2013). In the construction industry, process conformance and interoperability are emerging needs that are particularly important for improving management of large and complex projects.

This paper summarizes the concept and application of Industry Foundation Processes (IFP), a process modeling framework with certain features and characteristics that facilitate process conformance and improves process interoperability. IFPs are management processes that are developed according to the best-in-class construction industry practices to enable more consistent and scalable integration of best practices into process-aware information systems. This paper is comprised of three sections: (1) discussing the theory, and establishing a framework as well as an ontology for the IFP modeling system, (2) customizing a few IFP processes for the domain of industrial sector construction projects and implementing them in a workflow management system to investigate the applicability of the IFP concept, and (3) analyzing and validating the value of the IFP modeling system through functional demonstration of the benefits, via development of a conformance checking algorithm, and an IFP process interoperability model.

The examples and processes discussed in this paper focus on the domain of industrial construction projects. However, the concept and the methodology used in this study are broad, and thus can be used in other construction sectors as well as in other industries. The development and application of processes according to the IFP modeling system is anticipated to result in more effective adoption of industry best practices and enhanced process conformance and interoperability, with the end-result of improved project performance.

2 Background

Several research studies confirm that effective adoption of best practices improve project performance in terms of cost, schedule, and productivity (Kang et al. 2013; Lee et al. 2005; Shan et al. 2011). Well-known organizations, such as the Construction Industry Institute (CII), the Project Management Institute (PMI), and the Construction Owners Association of Alberta (COAA) develop and promote best practices for management of different aspects of construction projects. However, effective, systematic, and consistent adoption of best practices throughout the life cycle of a project and from project to project is not an easy task. Increasing use of process-aware information systems drives efforts to define practices, as much as possible, as workflow processes and to enact them through the workflow engines of process-aware information systems to improve adoption of best practices (Liu et al. 2010).

While employing workflow processes for adoption of industry best practices is an important step forward, consistent and effective implementation of such processes throughout different levels of the organization, and among the collaborating organizations, is a challenge. In reality, many best-in-class processes that are developed according to best practices by the most experienced process analysts are implemented differently in project information systems, and are not consistently used throughout the life cycle of the project. In addition, the implemented processes are not well connected to, and do not exchange information with, other existing processes of legacy information systems. As a solution, in large-scale projects the owner-operator or the main EPC contractor of the project typically offers a cloud-based software platform and enforces all project stakeholders to perform project communications, collaborations, and information exchange through that particular software platform. This integrated software platform cannot be easily connected to the legacy information systems of project participants, and thus inhibits process conformance and interoperability.

ISO 16739 –Industry Foundation Classes (IFC)– and ISO 15926 –Integration of life-cycle data for process plants including oil and gas production facilities– are well-known data interoperability standards in the domain of AEC/FM. The Information Delivery Manual (IDM) or ISO 29481 developed by buildingSMART expands the focus of interoperability to process interoperability. IDM, with an information management perspective, formalizes an interaction framework for delivery and exchange of Building Information Modeling (BIM) data between project stakeholders via describing the information processes and standardizing information exchange requirements (Shiva Aram 2010).

The proposed IFP system is a process development framework for management processes in the construction industry to integrate best practices, and to improve process conformance, and process interoperability, to address these emerging need of the construction industry.

3 IFP Modeling System and Processes

Industry Foundation Processes (IFP) form a process modeling system that facilitates integration of core processes of known best practices in the construction industry into workflow management systems and improves process conformance and interoperability. IFP processes are defined as workflow templates with essential activities and minimal features. Then, these features can be customized for specific types of projects and implemented based on projects conditions and requirements.

IFP workflow processes are structured processes with clearly defined sequence of activities and their execution constraints. They focus on the flow of information or work while abstracting from execution constraints, such as data dependencies and resource constraints. They are defined in their simplest form, containing all the essential steps, but with no extra or redundant activity. As such, they are general enough to be extendable to many situations, yet simple and streamlined (Golzarpoor, Haas, and Rayside 2016).

Workflow inheritance is an important property of the IFP modeling system that enables IFP workflow processes to be customized to more specific and more complex processes in a controlled manner to conform to particular types and characteristics of projects, while not losing their core structure and behaviour. The IFP modeling system can be used for modeling and implementation of different construction industry workflow processes, such as contract management, change management, materials management, and deliverables management, as simple structured processes that incorporate the essence of best practices (Golzarpoor, Haas, and Rayside 2016).

Implementation of the IFP system offers several practical advantages. It promotes adoption of best practices, provides a standard core structure for implementation of common processes, facilitates more consistent implementation of workflow processes in different projects, and brings visibility to the core structure of complex processes. In addition, process conformance and interoperability are also improved by the implementation of the IFP system. This system facilitates integration of best practices into workflow management systems, and supports their consistent implementation throughout project lifecycle and from project to project. It can be used to efficiently implement and manage systems of customized interoperable processes that conform to the best practices, and thus support improved project performance (Golzarpoor, Haas, and Rayside 2016).

3.1 IFP Development Approaches

Two principal approaches are proposed for deriving foundation processes:

1. A top-down approach in which foundation processes are defined as structured processes based on best practices in the construction industry.

2. A bottom-up approach in which the common core structure of different implementations of a construction workflow process is identified and extracted and is used as the basis for developing an IFP.

These approaches are illustrated in Figure 1.

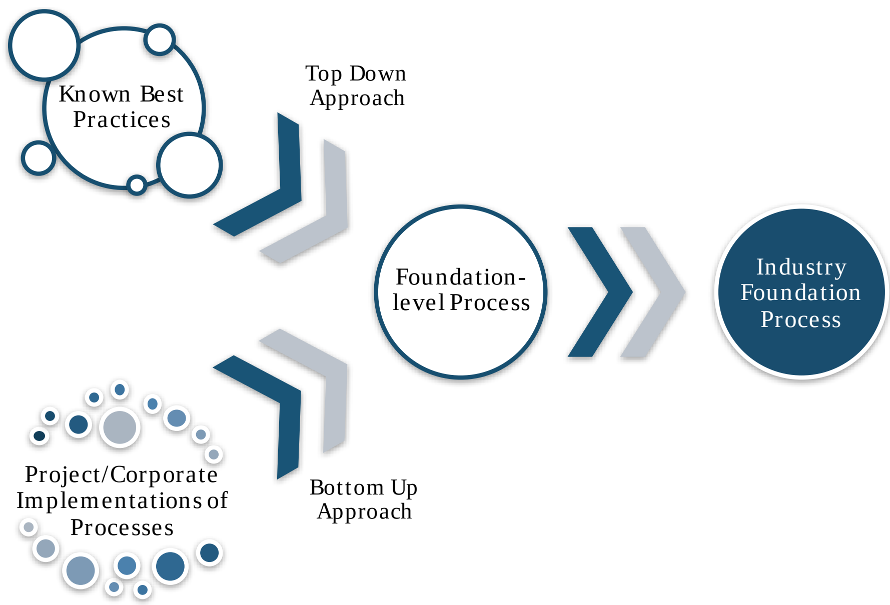

Figure 1: Approaches of Deriving Industry Foundation Processes

The former approach is used to develop a new workflow process based on existing practices, policies or regulations (Figure 2). It involves scrutinizing known best practices, developing high-level organizational processes that include the main steps for adopting those practices, transforming the organizational processes based on the roles and responsibilities of actors into structural processes implementable into workflow management systems, and defining foundation processes based on the core structure of those structured processes. A foundation process is the core structure of an IFP. Foundation processes are then equipped with additional features and properties, discussed in the next section, to facilitate process reusability, conformance and interoperability. Then, they are called IFPs.

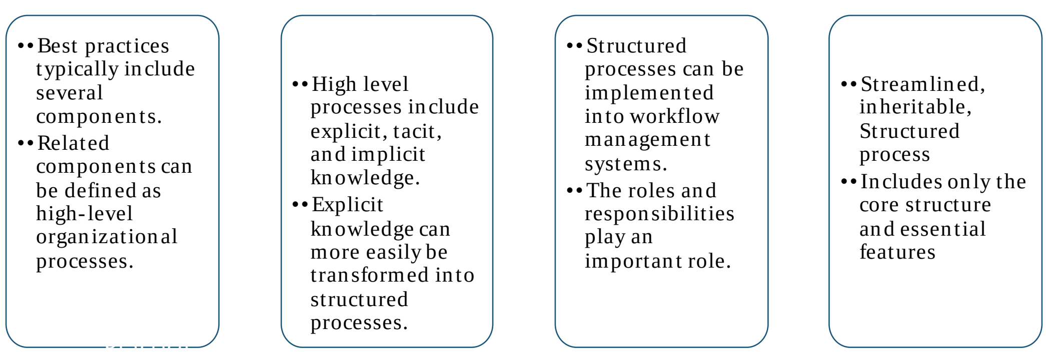

Figure 2: Transforming a Practice into a Foundation Process

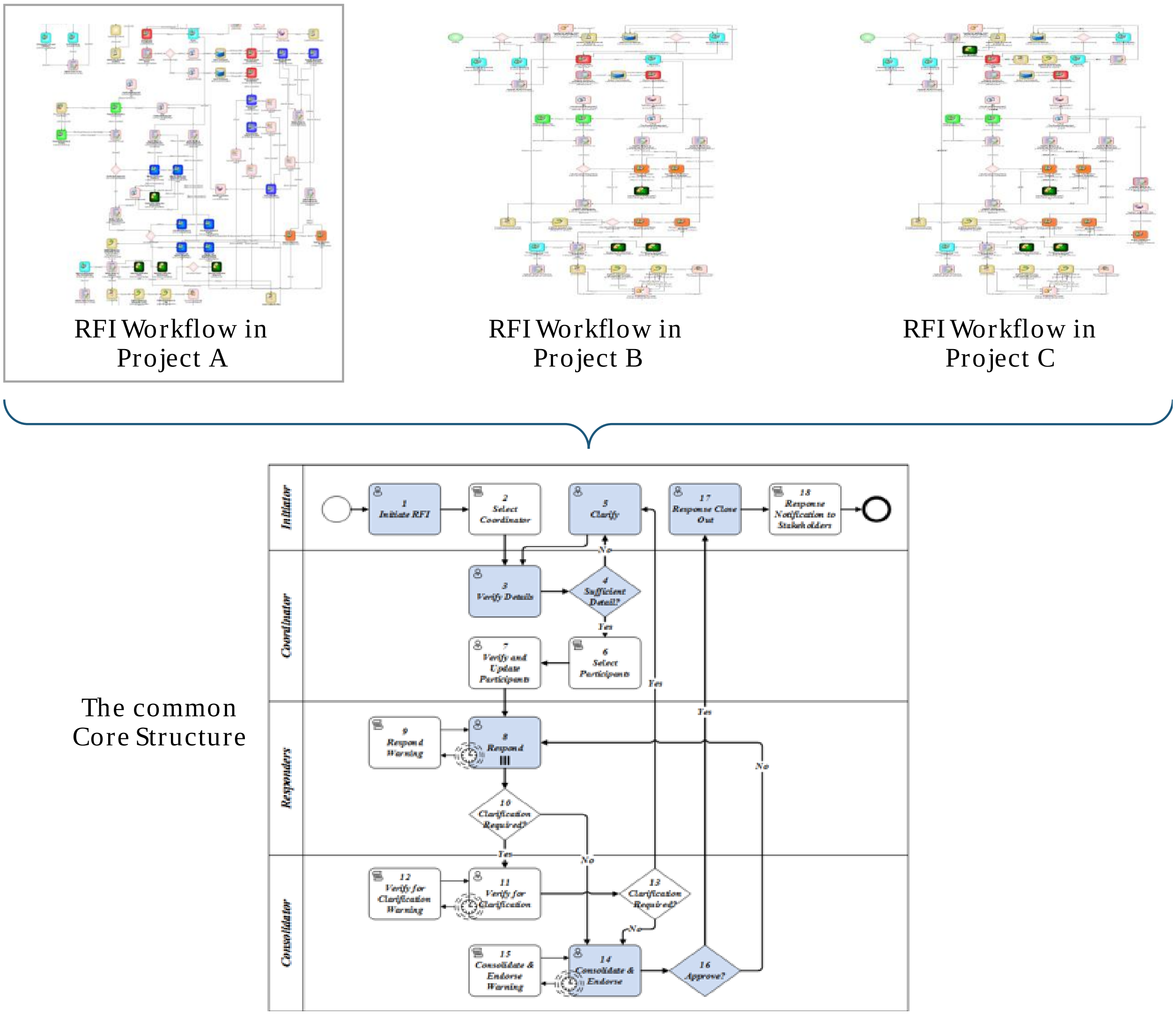

Figure 3: The Common Core Structure of the RFI Process Extracted from Three Implemented Processes

The latter approach can be used when a common workflow process has been used in different projects, and the implemented versions are available. This approach requires employing business process analysis tools and process modeling techniques to compare different implementations of a process and extract the common core of those processes as a basis for deriving a foundation process. An example of this approach is presented in Figure 3. In this figure, three implementation-level request for information (RFI) workflow processes that have been used in three different projects are shown at the top and the common core structure which has been extracted is shown at the bottom. These two different approaches are complementary and using a combination of both, if applicable, is recommended for deriving foundation processes.

3.2 IFP Ontology

Industry Foundation Processes are defined with particular features and properties to enable them systematically be customized, firstly for specific project types, and then for each project's conditions and constraints. These properties are defined as IFP ontologies. Based on a synthesis of the literature, examination of functional and operational requirements for the IFP system, and consultation with industry experts, eight components have been considered for the IFP ontology. Table 1 is a summary of these components.

Table 1: IFP Ontology Components

Ontology Components	Description
Version & Scope	Version number and process scope (e.g. oil and gas projects)
Core Structure	Core structure and functionality, i.e. main activities and relationships
Abstraction Level	Abstraction level to essential details using process maturity model
Data Structures	Sets of data structures associated with an IFP
Recommended Practices	Guidelines for how to perform human activities
Inheritance	IFP inheritance rules are the basis for conformance and interoperability
Conformance	Ensures conformance of customized processes with the IFP
Interoperability	Facilitates interoperability with other workflow processes

Among these components, this paper focuses on a brief summary of workflow inheritance and how IFP workflow inheritance is the basis for improving process conformance and interoperability. IFP workflow inheritance rules control how more detailed workflow processes are derived from an IFP, while maintaining conformance to the IFP. Three categories of workflow inheritance are proposed: (1) Structural, (2) Organizational, and (3) Temporal. The inheritance/conformance rules allow or restrict certain workflow transformations.

Structural inheritance rules restrict the flow of work or information in subclasses of a workflow to the sequence and set of core activities defined in a superclass IFP. This ensures that the core structure of an IFP process does not change, when it is customized to accommodate specific project requirements. Organizational inheritance rules ensure that the level and sequence of authorization defined in an organization or project is met with the execution of the workflow process. For example, if someone is not available who would be the next responsible person to whom the work or information be directed, or who could be assigned as a delegate for somebody who is not available for a period of time. Temporal inheritance rules define allowable durations for each activity according to regulatory or contractual obligations or industry best practices. For example, they focus on the amount of time that is allowed for an approval activity to be finalized according to regulatory, institutional, or contractual obligations.

4 IFP Validation

To validate the functionality of the IFP modeling system and to demonstrate its value and benefits the following research steps have been performed: (1) IFP and customized workflow processes for a few common construction industry processes have been developed, and they have been implemented in a workflow management system, (2) a conformance checking algorithm and an automated conformance checking tool have been developed to enable the comparison and conformance checking of workflow processes based on the workflow inheritance rules, (3) an IFP interoperability model is proposed to describe how workflow processes that are in conformance with IFP can more easily interact and exchange information. These research components are explained in more detail in the following sections.

4.1 IFP Deployment

Deployment of the IFP system encompasses three steps: (1) Developing an implementation framework that explains modeling of processes and how their customization to more detailed workflows using workflow inheritance rules, (2) modeling IFP and customized versions of workflow processes using the implementation framework, and (3) implementation of the modeled processes in a workflow management system and validating their functionality.

The implementation framework uses an event-driven state-machine modeling paradigm. An IFP workflow process, such as RFI-IFP, is defined as a finite state-machine model with core activities defined as state classes, such as initiate and respond, defined as state classes. Transitions from one state to another are triggered by users input that represent completion of one activity in the process model and moving the control forward to the next activity. Customized activities inherit from the core activities and customized workflows inherit from IFP workflows. Workflow inheritance rules govern the customization. Figure 4 presents this framework.

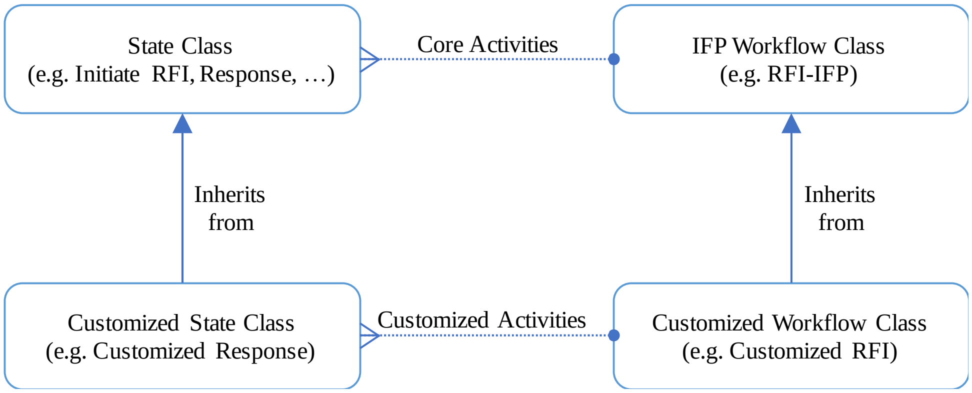

Figure 4: IFP Implementation Framework Using a State-Machine Model

The request for information (RFI) workflow has been selected for the IFP deployment. An IFP and two customized versions of the RFI process have been modeled using the above explained implementation framework. One of the customized versions is aligned with the IFP and meets all the conditions defined by the workflow inheritance rules, and the other is not. This is the basis for conformance that is explained in the next section.

Any workflow management system can be used for implementation of the IFP modeling system. In this research Windows Workflow Foundation (WF) has been selected as the deployment platform. WF technology is a component of Visual Studio, and is the Microsoft solution for modeling and enactment of long-running workflow processes. Windows Workflow Foundation 4.5 is part of .NET Framework 4.5, and offers a declarative programming environment. A workflow process can be defined as separate programming fragments that are called activities, and the relation among them. WF does not offer several features that business process management products offer, but provides a flexible platform for process model frameworks. Figure 4 is a snapshot of the RFI-IFP workflow implemented in the WF and visually represented as a state-machine model.

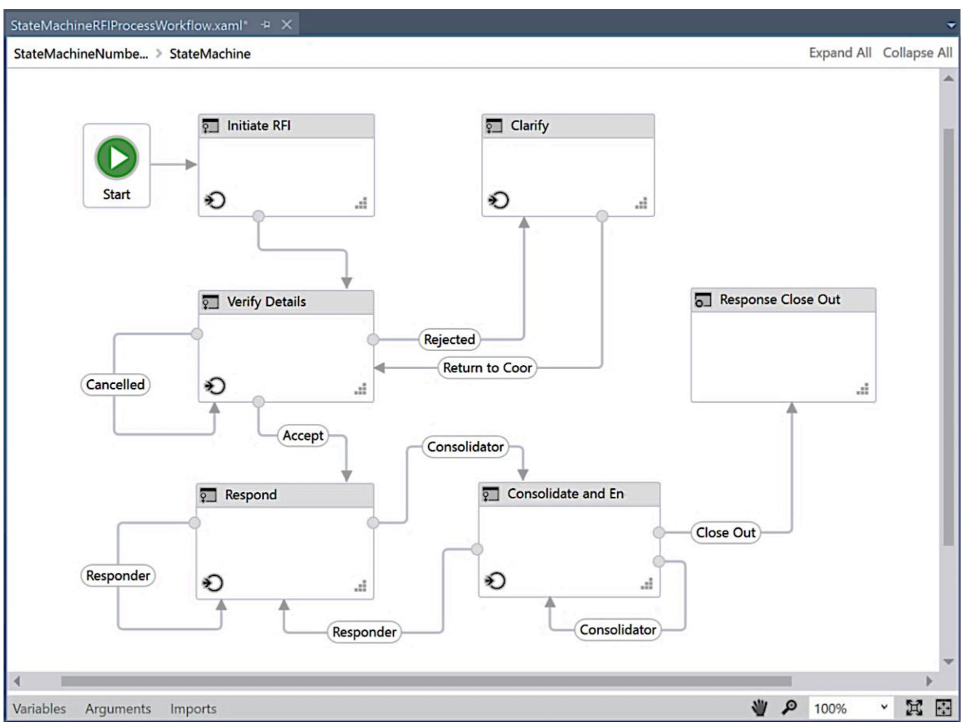

Figure 4: Implementation of the RFI-IFP Workflow as a State Machine Model

4.2 IFP Process Conformance

Construction projects have a lot in common. In every stage of the project from design and engineering to procurement, construction, and start-up, and from project to project, there are several organizational and management practices, activities, and procedures that are similar. Nowadays, and particularly in large-scale projects, these common activities, practices, and procedures are embedded into workflow processes and enacted through workflow engines of modern information systems. As a result, in the information systems of different organizations several processes can be identified that have been designed to perform similar tasks, and to manage particular aspects of the projects, e.g. design review and approval, contract management, change management, etc.

In spite of similarity, these processes, however, are defined differently from project to project, and are implemented differently in each project information system. In addition, they are typically customized for specific conditions and circumstances of a project, and are updated several times during the lifecycle of the project using a process improvement framework. The latest update of a process in one project has been specifically improved for using in that particular project and by no means is directly useful in another project. Moreover, the processes that are customized in an organization to suite specific projects may not be sufficiently in conformance with the general guidelines, practices, and policies of that organization. In brief, there is no standard or common core for similar processes.

As such, process conformance and conformance checking techniques are exceedingly important. Conformance checking techniques are useful to ensure that the actual behaviour of a workflow process is in conformance with the intended behaviour (Mannhardt et al. 2015). They can be used, for example, to ensure that the behaviour of a customized contract management workflow process, which is used in one project of an organization, is aligned with the general guidelines of that organization for contract management. Conformance checking techniques primarily focus on the control-flow of a process and abstract from other less significant aspects of the process, such as data dependencies and time constraints (Mannhardt et al. 2015).

IFP process conformance is a framework that relies on the IFP workflow inheritance concept to restrict particular modifications in the customized versions of an IFP process, and to ensure the customized process maintains alignment with organizational regulations, policies, and practices. As discussed, three categories of workflow inheritance have been defined – structural, organizational, and temporal. Organizational and temporal inheritance rules are being defined as properties of processes that can be inherited by the customized process, and can more easily be checked for conformance. Therefore, the main focus of the conformance checking is the structural conformance.

4.3 IFP Interoperability Model

Process interoperability is the interaction and collaboration of workflow processes among different information systems. Process interoperability facilitates cross-organizational cooperation and exchange of information to achieve a common goal. In the construction industry process interoperability is vital in both partnership situations, such as joint-ventures to accomplish a large complex project, as well as in Client-Supplier and Owner-EPC relations, in which workflow processes from information systems of different organizations interact and exchange information.

A familiar example is the interaction of inbound and outbound transmittal processes that facilitate exchange of engineering document packages between the information systems of two organizations. Outbound transmittals are also called submittals. Inbound and outbound transmittal processes are typically preceded by an allocation process. The allocation process is used to reserve document numbers for the transmittal package based on the recipient company’s document numbering schema, and to return those numbers to the originating company. The transmittal process, then, is used for the delivery of the package of documents. An outline of this interaction is shown in Figure 5.

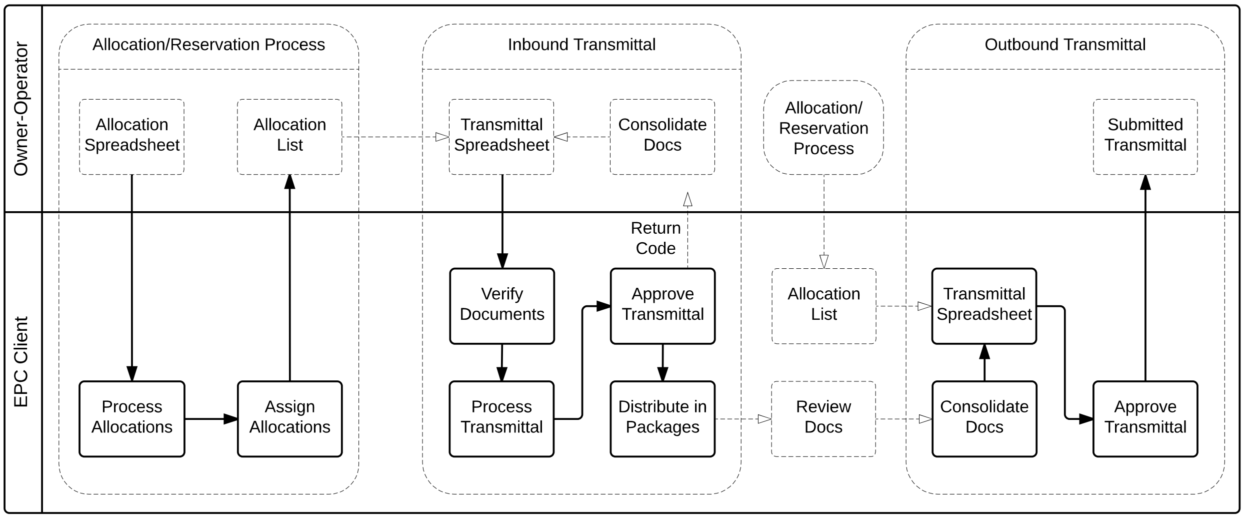

Figure 5: An Outline of Inbound and Outbound Transmittal Processes in a Construction Project

An IFP interoperability model is proposed in this paper to smoothen the exchange of information between processes and thus enable process interoperability. This model is outlined in Figure 6. According to this model process conformance is the basis for process interoperability, and the IFP ontology components are the vital components. Based on the IFP interoperability model, conformance of customized workflow processes to IFP facilitates processes interoperability, because of the common core and similar data structures they inherit from the IFP. The common structure, components, and behaviour of workflow processes that are in conformance with the IFP system facilitate more smooth interaction and exchange of information between those processes. The exchanged information is generally categorized into data fields, metadata fields, and attached documents summarized in Figure 7.

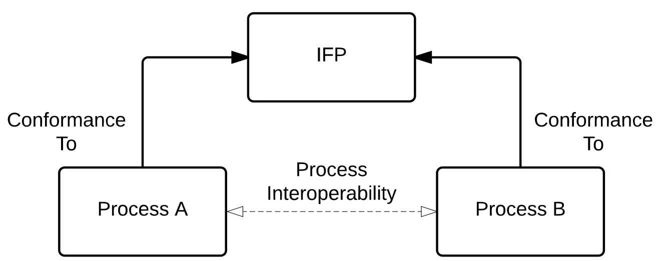

Figure 6: Outline of IFP Interoperability Model

Exchange Record		
Data Fields	Meta-Data Fields	Attached Documents
Include process specification, process technical, and project data	Include process and document meta-data	Include primary and markup files

Figure 7: An Overall Exchange Record

The IFP interoperability model employs the IFP ontology components, including the core structure, abstraction level, and data structures of interacting workflow processes, as well as the workflow inheritance rules to facilitate communication of workflow processes by exchange of: (1) high-level structure of interacting processes, (2) participants roles and hierarchy of authorization, (3) expected time-limits and the response due dates, (4) essential data structures (project and process data), and (5) state changes and process status updates.

5 Discussion and Conclusions

This paper summarized the definition, development approaches, ontology, implementation methodology, and the value and benefits of the IFP modeling system and its processes. The IFP modeling system offers a standard core for common workflow processes in the domain of the construction industry. The defined IFP ontology components facilitate improved process conformance and interoperability. Developing metrics and indicators for quantitatively measuring improvement in the levels of conformance to best practices and process interoperability are considered an extension of this research, and a future work.

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