Transaction formalism protocol tool in infrastructure management

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Abstract

Purpose – The purpose of this paper is to develop an eight-step procedure – transaction formalism protocol (TFP) – in the area of infrastructure management. The proposed TFP is developed from two perspectives: TFP Specification (conceptual) and TFP Tool (application). This paper introduces the TFP Specification and discusses the TFP Tool in detail.

Design/methodology/approach – To develop the proposed TFP Tool, a five-step methodology was used: identify and select existing standards, benchmark standards, link and build on these standards, develop the proposed TFP Tool and validate the protocol.

Findings – The TFP Specification defines each step as a function for which inputs, controls, mechanisms, tools/techniques and outputs are specified. The TFP Tool comprises a set of forms and guidance that the transaction development personnel, including transaction analysts, transaction designers, software developers, process modellers and industry experts, will use to define transactions in infrastructure management domain.

Practical implications – The proposed TFP Tool enables transaction development personnel to define transactions effectively and efficiently for information and communication technology (ICT)-based solutions through defining information in a structured, consistent and easy way.

Originality/value – The TFP Tool was built on existing standards incorporating their shortcomings, including lack of a step-by-step procedure to help guide the personnel what to do next, lack of transaction monitoring and improvement steps and lack of standardised forms to collect information in a prescribed format for implementation in ICT-based collaboration systems. The proposed Tool was evaluated and found to be feasible, usable and useful.

Keywords Transaction formalism protocol, Methodology, Communication, Transaction, Infrastructure management, Tool

Paper type Research paper

Introduction

Infrastructure organisations, like other industries, rely heavily on their information and communication technologies (ICTs) – the computer-based tools and data sets they use to carry out various business activities. ICT supports not only their internal operations but also their communication between groups that are both internal and external to the organisation. Traditional communication or information transactions – involve human-to-human exchanges of information. However, the ongoing trend towards increased use of computer-based information systems is heading towards increased instances of computer-to-computer information transactions (Rashid and Ahmad, 2013). Examples of information exchange (i.e. communication or transaction) between infrastructure organisations or between infrastructure management systems include communications

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during disaster response (e.g. is power available in this area? who is responsible for this section of roadway? when will water be restored to this area?); coordination between utility agencies to locate underground utilities before any excavations; or aggregating data from multiple infrastructure management software for the purpose of performing sustainability analysis or reporting to meet public sector accounting requirements. Unlike human-based communications in which the details of the information exchange are determined in a manual and *ad hoc* basis, computer-based communications must be much more formally defined and structured. Yet, this process of formally defining data transactions is not typically a common, easy or well-understood procedure within infrastructure organisations. Motivated by the goal of improving transaction design processes, the core question of this research is "how to formalise these transactions for computer-based collaboration?" Currently, there are some methodologies and standards for the design and management of work processes and communications, but these do not adequately address the main focus of this research work, which is to define message template (MT)-based information transactions in the domain of infrastructure management using a systematic procedure. The United Nation's Centre for Trade Facilitation and Electronic Business (UN/CEFACT) Modelling Methodology (UMM) (UN/CEFACT, 2003) and RosettaNet (Damodaran, 2004) define specific commercial transactions (buy/sell transactions), in contrast to more general information transactions. In comparison to message-based information exchange, the Information Delivery Manual (IDM) (IAI-IDM, 2007, 2012) defines a three-dimensional (3D)-object-based exchange of information. The Voorwaarden Scheppen Voor Invoering Standaardisatie –VISI (2007, 2011) lacks a step-by-step procedure that the industry experts can use in a way that is easy to understand, use and apply. There is a lack of a structured process or guideline in the current literature to provide the sequential steps of process modelling and simulation to cover all elements of a successful end-to-end process (Safari, 2016), emphasising on the need to develop a step-wise procedure that the transaction development personnel (including transaction analysts, transaction designers, software developers, process modellers and industry experts) will use to define transaction specifications effectively and efficiently.

In response to the research question, an eight-step procedure – transaction formalism protocol (TFP) – was developed from two perspectives: the TFP Specification and TFP Tool. The TFP Specification represents a conceptual model that defines each step as a distinct function for which inputs, controls, mechanisms, tool/techniques and outputs are specified. The TFP Tool comprises a set of forms, guidance and instructions developed so that the transaction development personnel can easily understand and apply it in the domain of infrastructure management while defining transactions for ICT-based collaboration systems.

The proposed TFP Tool provides a holistic approach to transaction design, implementation, monitoring and management. It incorporates sufficient support on how to use the forms to make it easy to understand and apply in different industries, including construction.

The TFP Tool was applied to formalise a process of reporting on the inventory and condition of infrastructure systems between different public organisations – a process called "capital asset reporting", which was identified in an industry survey (Zeb *et al.*, 2012) as one of the transactions that has the greatest potential for ICT improvement. The TFP Tool is one part of a larger research program examining computerised information transactions for infrastructure management. The overall research programme is shown in Figure 1, reflecting main research component and associated outputs that are organised at the following three levels of abstraction:

Develop TFP Specification: a conceptual model of the proposed protocol was developed, which is referred to as TFP Specification (Zeb and Froese, 2014b). The proposed protocol allows a transaction designer to formalise a transaction in terms of transaction maps (sets of sequenced atomic transactions) and message templates (representing header and payload

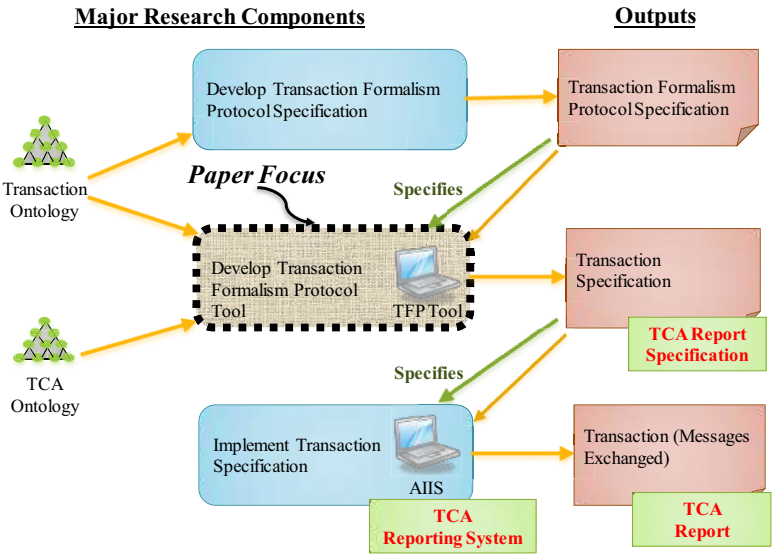

Figure 1.
Core research components and outputs – develop TFP Tool (paper focus)

information in a structured format). The protocol draws upon the Transaction Domain Ontology, Trans_Dom_Onto (Zeb and Froese, 2012), for elements that make up the design, implementation and management of the transaction map and message template header information (meta information about a message template).

Develop TFP Tool: the TFP Tool (the focus of this paper) implements the protocol specification in the form of a software application. The protocol tool comprises a set of forms developed to create standard transaction specifications. The proposed Tool was developed such that the "analyst" will use to define transaction specifications. In this research work, the TFP Tool was applied to formalise and create the Tangible Capital Asset (TCA) Reporting specification. For the message template payload information (the body of the information that is exchanged in a transaction), the Tool uses the terms represented in different ontologies and data models depending upon the area of application. For the TCA Reporting transaction, the payload information was captured from the Tangible Capital Asset ontology, TCA_Onto (Zeb and Froese, 2014a), developed as part of this research. The message header information (meta information about the message and transaction) was captured from the Trans_Dom_Onto.

Implement transaction specification: an end-user will carry out individual transactions in accordance with the transaction specification. Often, the transaction specification will be implemented into a piece of software by the software developers (programmers), and the end-user need not have knowledge of the transaction specification. As part of this research, the TCA Reporting specification was developed, which was then implemented in a prototype Asset Information Integrator System, AIIS (Zeb *et al.*, 2015). This is a web-based prototype reporting system that is to be used by different municipalities to report their Tangible Capital Asset information to the provincial government for financial planning and budget allocation.

Related work process and communication formalisation standards

Currently, some work process and communication formalism methodologies and standards do exist in various industries – both within and without the architecture, engineering, construction and facilities management (AEC/FM) industry. These methodologies and

standards do not completely address the needs of transaction formalism in the domain of infrastructure management. A brief review of the most relevant standards is as follows.

In non-AEC/FM industries, the open electronic data interchange (ISO, 1995) focuses on modelling and standardising business documents that are exchanged between the parties. The complexity, high cost of implementation and high transaction costs are among its disadvantages. The UMM (UN/CEFACT, 2003) focuses on modelling and formalising commercial transactions (buying/selling). The electronic business Extensible Markup Language (ebXML) is a set of specifications that enable organisations of any size, located in any geographical area, to conduct business over the internet (ISO, 2004/2005), while the RosettaNet system formalises communications along the supply chain organisations in the electronics industry (Damodaran, 2004). The UMM, ebXML and RosettaNet provides specifications for a specific set of commercial transactions, and they do not define a detailed procedure for how others can produce their own transaction specifications. In contrast, the objective of this research work is not to pre-define specifications for particular types of transactions, but rather to provide a process for practitioners to define their own transaction specifications to meet their individual needs. Each of these existing standards includes a component that provides semantics of the terms used in the specifications (called the "core component" in the UMM and ebXML; and called the "dictionary" in RosettaNet), whereas the TFP achieves this by developing ontologies.

A number of researchers have developed methodologies for business process modelling. Among these, Villarreal *et al.* (2006) have developed a model-based development process methodology that lacks the specification of a procedure that describes how to capture business processes and information requirements for the design of messages. Kim (2002) has developed a standardised schema to formalise business processes, but this approach lacks the complete procedure used to define business processes – it is not a complete methodology as it depends on the UMM for the design of business processes. Kramler *et al.* (2005) have developed a methodology to support the use of web service technologies in business collaboration in terms of modelling and delivery of process models; however, this does not include the way that information exchange requirements and message templates are defined. Bauer *et al.* (2004) developed a model-driven approach to design cross-enterprise business processes; however, it does not elaborate on the information modelling associated with these business processes.

A set of business process improvement methodologies was developed to enhance administrative, operational and technical efficiencies and effectiveness of a variety of organisations. Lee and Chuah (2001) developed a five-phase super methodology to formalise work processes based on a combination of three approaches: business process improvement, business process re-engineering and business process benchmarking. The super methodology lacks to provide guidance on the design and management of transactions for ICT improvements. The total quality management is a four-phase methodology devised to focus on customer satisfaction, process formalism and defect reduction in product-oriented organisations (Anderson *et al.*, 2006). It is a system of practices, tools and training methods; however, it lacks to provide a structured approach to define and improve work processes and communications for computer-based communication systems. In addition, guidance on implementation support is also not provided. Dragolea and Cotirlea (2009) devised a five-phase methodology to guide organisations to benchmark their work processes, strategies and products with that of a successful organisation; identify gaps; and consequently adopt best practices. The benchmarking methodology lacks the procedure on how to define work processes and communications. The plan-do-check-act – PDCA – is a four-step methodology developed by Walter Shewhart to improve business processes continuously through comparing actual results with set-forth targets (Sokovic *et al.*, 2010). The focus of the PDCA is to assess overall quality of the business processes rather than designing and managing work processes and

communications specifically for ICT improvements. In addition, the PDCA lacks to identify and define actor role that is an important element of work process and transaction design, implementation and management. Six-Sigma is a five-phase quality improvement methodology developed to identify and assess errors and defects in the operational work processes using root-cause analysis by concentrating on outputs. Similarly, Lean thinking is a five-phase approach developed to examine redundancies in the workflows and deleting all activities, adding no value to organisations (Radnor, 2010). The concept of lean process improvement is often combined with Six-Sigma to develop a Lean Six-Sigma methodology (Buavaraporn, 2010). The Lean Six-Sigma looks into work flow redundancies and overcome inefficiencies, whereas the Six-Sigma focuses on identification, assessment and treating defects through root-cause analysis. Both of these methodologies focus on the quality of organisational work processes rather than designing work processes and communications for ICT-based software implementations. The model-based integrated process improvement methodology was developed by Adesola and Baines (2005) with specific focus on business process improvement and re-engineering. It is a seven-step methodology devised to formalise work processes instead of communications and lacks to provide what and how information is to be captured in a structured way.

In the AEC/FM industry, the IDM (IAI-IDM, 2007, 2012) is a requirement specification methodology that formalises work processes in the building segment of the construction industry. This standard focuses on 3D model-based exchange of information between partners using Building Information Models (BIMs), but it does not meet the requirements of a general communication methodology for the design and management of transactions in the domain of infrastructure management. According to Berard and Karlshoej (2012), the exhaustive nature of the IDM makes it time-consuming to develop and difficult to share with others on projects. The IDM has some features that are relevant to this research work, which were used in the development of the proposed protocol with modifications. Moreover, the BIM project planning execution guide (PSU, 2011) assists experts to define the BIM execution strategy over the life cycle of projects. The core emphasis is on 3D-object-based exchange of information in the building segment of the AEC/FM industry, in comparison to message-based exchange of information between the partners in the domain of infrastructure management. The model view definitions (MVD) (IAI-MVD, 2005) standard guides the software developers to define and implement a subset of the industry foundation class (IFC)-based BIM effectively and efficiently into software applications. The MVD is BIM-specific and lacks a systematic procedure for capturing exchange requirements. The VISI (2007, 2011) standard is a Dutch communication standard developed for the design of transactions in the AEC/FM industry; however, it lacks a step-be-step process to define As-is and To-be transactions and capture exchange requirements. The VISI standard depends on the VISI system that defines XML-based message templates for owner-general contractor transactions in the context of the Dutch construction industry. The construction objects and integration of processes and systems engineering method standard is developed to create agreements on working methods and organisation of production processes and information (Schaap *et al.*, 2008). This standard formalises 3D-object-based exchange of information, rather than message-based communications, and it lacks a systematic procedure for needs assessment and information requirements specification.

The current standards and methodologies lack a systematic procedure to define transaction specifications in the domain of infrastructure management. Most of the standards are work-process-centric rather than communication-centric. Most do not address how to assess needs and capture information that is required in a given communication. Most of the standards are IT-expert-centric and are not suitable for the end-users. Of these existing methodologies, the IDM provides a good exemplar for the development of the proposed TFP. The IDM arose out of efforts within the international BuildingSMART community to

establish the IFC as an open BIM exchange standard. After many years of developing these BIM exchange standards, adoption was slow, in part because it was difficult to implement these standards both in software and in end-user's work practices. Over time, it was determined that adoption could be improved if the BIM exchange processes are formally designed, documented and agreed upon – the IDM was then developed to support these formalisms of the BIM exchange transactions. The proposed TFP is intended to play a similar role in the infrastructure industry data transactions that the IDM plays for IFC-based BIM transactions. The development of the proposed Tool in the domain of infrastructure offers a contribution to the existing body of knowledge from a theoretical perspective; however, from practical and application perspective, the purpose of the proposed TFP Tool is to enable transaction development personnel to define transaction for ICT-based collaboration systems effectively and efficiently through: capturing structured information; achieving consistency; and making the process easy to use and apply.

This paper will next discuss the development methodology, protocol architecture, a brief introduction of the TFP Specification, a description of the forms of the TFP Tool and its application as a process formalisation Tool. Towards the end, the TFP Tool validation and conclusions are presented.

Methodology to develop the proposed transaction formalism protocol

In this research work, a process formalisation Tool was developed to define transactions effectively and efficiently for implementation in ICT-based collaboration systems in the area of infrastructure management. Hence, the unit of analysis focuses on information flows – transactions that are composed of transaction map, message templates representing both the header (meta information about a message; e.g. from, to or date, etc.) and payload information (actual information content that is required to be exchanged in a given transaction) and actor roles (i.e. sender and receiver in a given transaction). Some of the content of this unit of analysis is generic, (e.g. header information); however, the rest of the content is very dynamic in the domain of infrastructure management, which changes with the context, including project type, delivery mechanism, process type and sender/receiver roles and their needs, etc.

This research work follows a modified version of the methodology proposed by Adesola and Baines (2005), who developed a business process improvement methodology consisting of two steps: reviewing and analysing current standards and selecting the most related ones based on a set of selection criteria. This research began with a review of the state-of-the-art methodologies and standards as part of the literature review and found that related approaches existed; however, they did not fully meet the requirements of this research work (i.e. a step-by-step procedure over the life cycle of a transaction specification). The proposed research methodology adopted a principle of building upon the best practices of the existing standards. Consequently, the following five-step approach was devised and is shown in Figure 2.

Step 1: This is to identify and select candidate standards. A set of the most relevant work process and communication formalism standards and methodologies were identified. In the AEC/FM industry, the most relevant standards were IDM and VISI. These standards were selected based on a sole criteria – relevance to the domain of interest (i.e. work process and communication formalisation standards in the area of infrastructure management).

Step 2: This is to benchmark existing standards. The selected standards were benchmarked in terms of general description, objectives and core components of each standard. The shortcomings of each standard were identified in relation to non-availability of the support for the design, implementation and management of transactions in the domain of infrastructure management.

Step 3: This is to link and build on existing standards. The proposed TFP was developed by building upon the existing benchmarked standards. Some related concepts (components) were chosen from the selected standards, which were then modified and used to develop the proposed protocol. A link was established between different components of the selected standards and the proposed protocol to show how various components were interrelated and how the proposed protocol was built as discussed in Zeb and Froese (2014b).

Step 4: This is to develop transaction formalism protocol. The proposed protocol was developed using the modified version of the most relevant and important concepts (components) identified. A step-wise procedure was developed to describe how to capture, define and implement these components and integrate them with the proposed TFP Tool, because it:

- represents a logical sequence of activities towards transaction formalism in the domain of infrastructure management;
- builds on existing standards that did not include the review, implementation and monitoring tasks in the process of transaction formalisation; and
- provides an easy to use and complete description of task required to formalise transactions.

Step 5: This is to validate transaction formalism protocol. The proposed TFP Tool was validated through an expert interview approach using a set of criteria; feasibility, usability, usefulness (Adesola and Baines, 2005) and generalisability. Five experts (A, B, C, D and E) were selected based on two criteria:

(1) expertise in one of the infrastructure sectors; transportation, water, wastewater and solid waste management; and

(2) knowledge of data modelling, transaction design, process modelling, etc.

Expert interviews were conducted using a structured questionnaire in three sessions: introduction (to understand the protocol), comprehension (to understand the forms to be used for data collection) and execution (answer the questions reflected in the questionnaire). All answers were recorded on an agreement continuum rating system: unable to rate (0), strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4) and strongly agree (5). More details are given in the subsequent validation section.

Transaction formalism protocol architecture

The TFP protocol is an eight-step procedure developed to define transactions in infrastructure management. The protocol was first developed as TFP Specification,

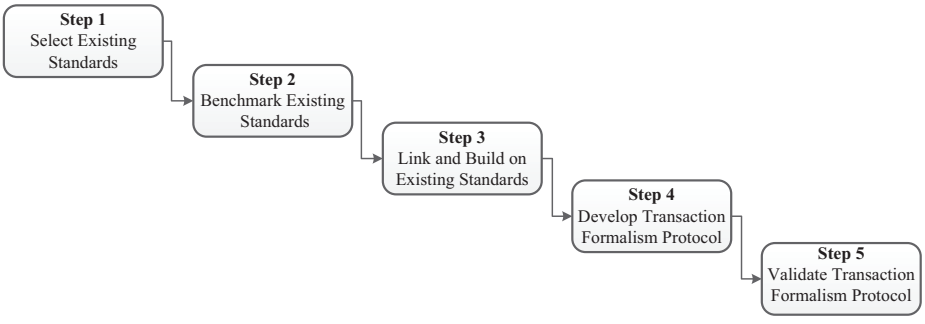

Figure 2.
Methodology to develop the transaction formalism protocol tool

explicitly describing the processes and how to perform them, which includes a set of guidelines, instructions and information for formalising a transaction. To further support this process and make it easier for development personnel to formalise transactions, the protocol was further developed in Excel as a form-based Tool – the TFP Tool – that can lead users through the steps to produce formalised transactions. As shown in Figure 3, a protocol architecture is presented to differentiate between the proposed TFP Specification and TFP Tool to capture the big picture. The TFP Specification was developed from a conceptual perspective where each step of the protocol was modelled as a distinct function for which inputs, controls, mechanisms, tools/techniques and outputs were defined. The TFP Specification provides the formal "instruction set" for creating transaction specifications. On the other hand, the TFP Tool implements the TFP Specification in the form of an application that is to be used to formalise transactions. The TFP Tool includes a set of Excel-based forms and guidance developed for specific steps of the protocol. Forms are developed for Steps 1, 2, 3, 4, 6 and 8 to capture information easily, accurately and consistently while defining transactions. For Steps 5 and 7, only guidance is provided on how to perform these steps, because no data are required to be captured in these steps.

It is important to clarify the difference between the TFP Specification and Tool from the business improvement perspective. The Specification is an abstract conceptual model representing a set of steps for which inputs, controls, mechanisms and outputs were defined, but it does not explain how to perform a step and what information is needed in each step as part of transaction formalisation for ICT improvements. On the other hand, the proposed TFP Tool includes a set of forms explaining how to perform a step and what information needs to be captured in each step. The proposed Tool makes the process of transaction formalisation for ICT improvements: easy, consistent and structured. A brief introduction of the TFP Specification and a detailed description of the TFP Tool is as follows.

Introduction to transaction formalism protocol specification

To develop the proposed TFP Specification, two process modelling techniques were considered: Integrated Definition for Function Modelling – (IDEF0) (NIST, 1993) and Business Process Modelling Notation (BPMN) (Robert *et al.*, 2012). The IDEF0 technique is good to model top-down abstract processes where more detail in not required; however, the BPMN is used for detailed modelling at the lower level to define horizontal process flows, information object flows, activity timings, decisions, process simulations, etc. The proposed TFP Specification is an abstract top-down process model where more detail was not required at the conceptual stage; therefore, IDEF0 technique was adopted to develop the TFP Specifications. Other advantages of the IDEF0 include easy to use, ensure consistency in process models, supported in a variety of commercially available applications and time-tested.

The IDEF0 technique treats each step of the TFP Specification as a distinct function for which inputs, controls, mechanisms, tools/techniques and outputs were defined as shown on the left of Figure 3. A rectangular box represents each step, with arrows flowing in or out showing inputs (left), controls (top), mechanisms (bottom) and outputs (right). In addition, tools and techniques were identified to carry out each step. Inputs are data or objects that are required by a function to transform into useful outputs. Controls refer to various conditions required to transform inputs into correct and useful outputs. Mechanisms are means used to perform a function through transforming inputs into useful outputs. Tools/techniques include the necessary support or aid in terms of the procedures and software to perform a step efficiently. Outputs are data or objects produced as a result of accomplishing a function. The definition of each step of the protocol and the way it can be applied in practical scenarios

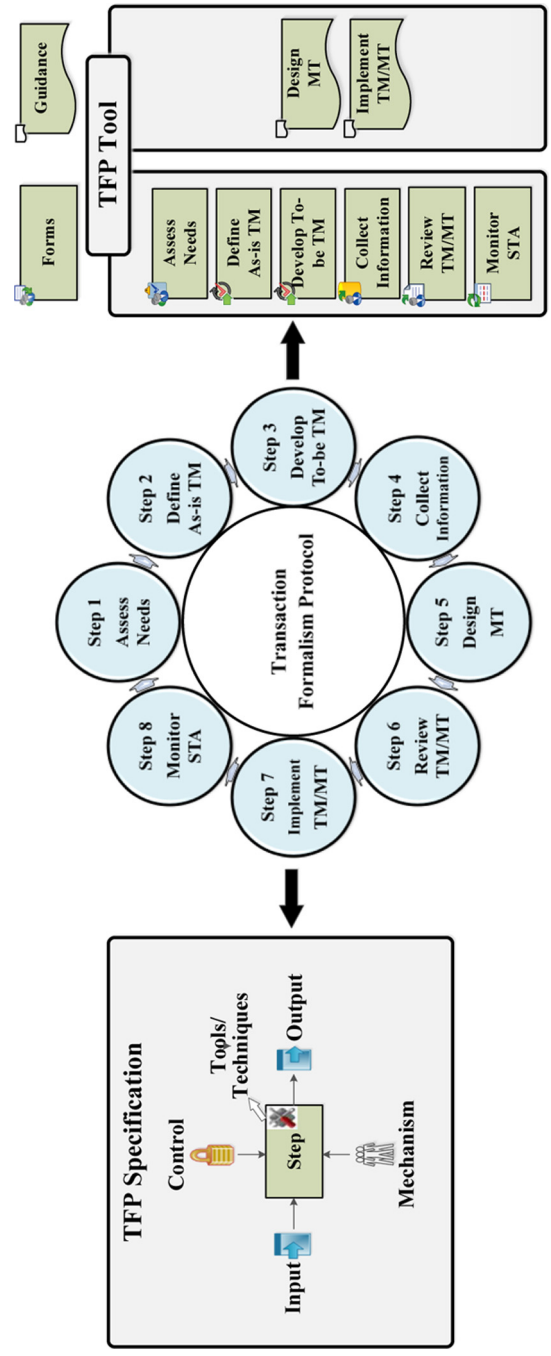

Figure 3.
TFP architecture

is elaborated in the subsequent sections. A detailed description of the inputs, controls, mechanisms, tools/techniques and outputs is given in Zeb and Froese (2014b).

Transaction formalism protocol tool development

The TFP Tool comprises a set of the digital forms (implemented in Excel) that transaction development personnel can use to formalise transactions to support ICT improvement.

Step 1 – assess needs

As shown in Figure 4, the assess needs form is used to support the process of listing different transactions that may be found within a given context and selecting those that are to be the subject of the formalisation effort. The technical information captured by the form includes a free-form description of the process used to identify and select transactions (including rationale for the selection and the assessment criteria used to assess transactions for ICT improvements), as well as a structured representation of the assessment criteria used to rank potential transactions. The user lists one or more transactions that are of potential interest. A rigorous and objective assessment is not required here, but a simple criteria-based assessment can assist the users to organise their ideas about the relative importance of different facets of the potential transactions. The criteria provided for organising the set of transactions record whether the transactions are conducted manually (paper-based rather than electronically); particularly critical, costly or frequent transactions for the organisation; likely to be managed transactions; considered to be complex; and required by contracts or regulations.

Each criterion is kept subjective so that users have the flexibility to identify transactions for ICT improvement in accordance with their specific environment and context. Use of criteria is kept simple through clicking the criterion that applies during the transaction identification and selection. A total score is calculated by simply adding the number of criteria that apply to each transaction, with higher scores indicating that the transaction more fully meets the defined criteria. This is intended only to provide some guidance to the users who can take broader issues into consideration to choose the highest priority transaction.

Step - 1 Assess Needs									
General Administrative Information									
Name									
E-mail Address									
Date Conducted									
Technical Information									
Description of Transaction Selection									
Assessment Criteria - (tick all that applies)									
Single or List of Transactions	**Manual/ Paper-based**	**Critical**	**Costly**	**Frequent**	**Liklihood of Mgt.**	**Complex**	**Contractual Requirement**	**Regulatory Requirement**	**Total Score**

Figure 4.
Assess needs – sample form

Step 2 – define the As-is transaction map

Once a transaction is identified for ICT improvements, the next step is to define the As-is transaction map (As-is TM). The term "As-is" refers to the way communication is taking place between the parties currently. Use case and expert interview approaches can be used to define the As-is TM. To define the As-is TM, a form was developed as shown in Figure 5, which includes technical information describing the definition, purpose, scope, specification, graphical representation and As-is performance of the As-is TM.

The As-is TM specification defines the sequence of atomic transactions (single communications between parties) that make up the TM, including the sending and receiving roles, the communication mode (e.g. e-mail, telephone, fax, postal mail, etc.) and a graphical representation. Finally, the form captures the performance of the transaction in terms of time (person-hours to complete the transaction), cost and quality (refers to overall effectiveness in terms of: message interpretability; message structuring; and ease of handling, tracking and retrieving a message). The subjective rating criterion of high, medium, low and none/not at all easy/not applicable were used. Documenting the As-is transaction performance is kept simple and optional because of the non-availability of the objective performance data and the difficulty to determine or get access to such data, if available. Using these rating criteria, the As-is transaction performance is benchmarked through establishing performance targets for the To-be transactions.

Step - 2 Define As-is Transaction Map						
General Administrative Information						
Name						
Identifier						
Change Log	Date	Status		E-mail		
Technical Information						
As-is transaction map definition, purpose, and scope:						
As-is Transaction Map Specification						
Name of Atomic Transaction		From		To		Mode of Communication
Generic Name	Specific Name	Designation	Organization	Designation	Organization	
Graphical Representation						
This space is reserved for hand-written sequence diagrams that are to be created based on As-is transaction map specification. Later these diagrams are to be tranformed to a formal sequence diagram using UML or any business process modelling application.						
As-is Transaction Performance Criteria						
Time (person-hrs)	Rate	Cost ($)	Rate	Quality		Rate
Transaction formulation time		Transaction formulation cost		Level of message interpretability		
Transaction transmission time		Transaction transmission cost		Level of message structuring		
				Ease of handling, tracking & retrieval		

Figure 5.
Define As-is transaction map – sample form

Notes: Rating criteria is "H" for high, "M" for medium, "L" for low and "N" for non or not at all easy or not applicable

Step 3 – develop the To-be transaction map
The To-be TM is the proposed improved way of conducting the As-is communication. The form, shown in Figure 6, is the same as for the As-Is TM, except that it explicitly describes the proposed improvements to the overall process and to each atomic transaction.

Step 4 – collect information
The TFP Tool next moves on to develop the detailed attributes of each atomic transaction that makes up the proposed data exchange process. The information contained in each message includes both header and payload information.

Figure 7 shows the form used to specify the attributes of the header information. The first part lists several common attributes which the developer can indicate as being required, optional or not applicable. These attributes include references to underlying data models or ontologies; delivery information such as sender/receiver roles and addresses, message timing requirements and security levels; and attributes that identify and classify the message and transaction type. A second section is similar but allows attributes that are specific to a particular location rather than common for all transactions.

Figure 8 shows the form used for describing the payload information that characterises the actual data content that parties need to exchange to accomplish a transaction successfully.

This information is to be identified and defined for each atomic transaction and would typically be derived from some type of underlying data model (e.g. as required by a specific software application). Each payload data item is given a name, a description, a ranking of required, optional, or not applicable and a series of transaction-specific classifications.

Step 5 – design message template
The MTs are designed based on the header and payload information collected in the Step 4. This information is represented in the MT in a well-structured and computer interpretable format that is exchanged between the parties in atomic transactions. No specific form is developed for this step; however, general guidance is presented on how to create a well-structured and computer-interpretable MT for an application area.

To achieve message-based interoperability between information systems of the infrastructure organisations, the MTs should represent the header and payload information in a computer interpretable format, i.e. the information is to be captured from an information model or ontology. The transaction development personnel are not restricted to use a specific information model or ontology; rather, they have the choice to use any ontology that best supports the design of the MTs in a specific application area. In this research work, MTs were defined for the capital asset reporting (application area) in which the header information was captured from the Transaction Domain Ontology (Zeb and Froese, 2012) and the payload information was captured from the Tangible Capital Asset Ontology (Zeb and Froese, 2014a).

A set of tools and techniques are available to define message templates; however, in this research work, Microsoft InfoPath was used to define MTs for the capital asset reporting due to low cost, ease of use and availability. The formalised MTs are then implemented, for example, as part of a web-based application for the exchange of information in each atomic transaction between different parties.

Step 6 – review To-be transaction map and message template
It is important to review the To-be TM and formalised MTs prior to implementation. The transaction development personnel should carry out the review process in joint consultation with industry experts. The purpose is to identify shortcomings and propose modifications, if any, to accurately represent industry requirements. Figure 9 shows a review form which identifies any changes required to the proposed transaction as a result of the review process.

Step - 3 Develop To-be Transaction Map												
General Administrative Information												
Name	$tm_{to\text{-}be\_}$ tca_reporting											
Identifier												
Change Log	Date (dd/mm/yy)		Status		E-mail							
Technical Information												
Summary of Proposed Improvements:												
To-be Transaction Map Specification												
Name of Atomic Transaction			From		To			Proposed Improvements				
Generic Name	Specific Name		Designation	Organization	Designation	Organization	Process Improv.	Infor. Improv.	Mode Improv.	Description of Proposed Improvements		
Graphical Representation												
Two formal sequence diagrams are created in UML for the To-be transaction map specification mentioned above using the generic and specific names from general user and developer perspective.												
To-be Transaction Performance Criteria												
Time (person-hrs)	Rate	Cost ($)	Rate	Quality	Rate							
Transaction formulation time		Transaction formulation cost		Level of message interpretability								
Transaction transmission time		Transaction transmission cost		Level of message structuring								
				Ease of handling, tracking & retrieval								

Notes: Rating criteria is "H" for high, "M" for medium, "L" for low and "N" for non or not at all easy or not applicable

Figure 6.
Develop To-be TM – sample form

Step - 4 Collect Information																		
Specification of Header Information																		
Name of Atomic Transaction, (To-be Transaction Map)	Rank Header Info.	Preamble Header Info.	Delivery Header Info.										Service Header Info.					
		Reference Info.	Actor Info.	Actor Role Info.		Temporal Info.						Security Info.	Transaction General Info.				Message General	
		Header Information Attributes - NOTE: Apply tick "√" all that applies																
		Data Model/ Ontology Version	Name/Address/ Fax/Tel	Role TrackingID	Sender/Receiver Role	Transaction Duration	Transaction Start/End Date	Message Duration	Receipt/Accept Signal Duration	Respond to Action Duration	Message Sent/ Receivd Data	High/Medium/ Low	Transaction Name	Transaction Purpose	Transaction Definition	Transaction Affiliation	Message Purpose	Message Definition
	REQ																	
	OPT																	
	N/A																	
Specification of Location Specific Header Information; if any.																		
Name of Atomic Transaction, (To-be Transaction Map)	Rank Header Info.	Preamble Header Info.	Delivery Header Info.										Service Header Info.					
		Header Information Attributes - NOTE: Apply tick "√" all that applies																
	REQ																	
	OPT																	
	N/A																	

Figure 7.
Collect header information – sample form

Step - 4 Collect Information																					
Specification of Payload Information																					
Name of Atomic Transaction, (To-be Transaction Map)	Payload Information	Rank Payload Information			Attribute(s) of Payload Information																
	Description	REQ	OPT	N/A																	
Location Specific Payload Information; if any.																					
Name of Atomic Transaction, (To-be Transaction Map)	Payload Information	Rank Payload Information			Attribute(s) of Payload Information																
	Description	REQ	OPT	N/A																	

Figure 8.
Collect payload information – sample form

Upon completion of the review, all of the key deliverables that describe the proposed transaction are finalised and assembled into a formal transaction specification that includes the final To-be TM, the content and format of the final MTs, the identified actor-roles and all the forms that are filled with the required information towards finalisation of the TM and MTs. The review of the To-be TM and MTs can be accomplished using expert review approach, where experts are provided with the review form through a questionnaire. Accordingly, a questionnaire was developed to review To-be TM and MTs defined for the capital asset reporting.

Step 7 – adopt and implement the transaction specification

Once the review is completed and the transaction specification is finalised, it is then implemented in software applications. No specific form is developed for this step, but rather some guidance is provided on how to implement transaction specifications in ICT systems. The transaction development personnel either adopt already developed transaction specifications by other parties or develop their own specifications. Implementation of transaction specifications ranges from a simple case, e.g. a data set exchanged in the form of a spreadsheet file transmitted as an email attachment, to a complex case where custom software applications are developed to implement transaction specifications. A pilot solution was proposed in this research work that falls between these two extremes. The pilot solution was developed for capital asset reporting between the municipal and provincial government. In the proposed pilot solution, the transaction specification was implemented as a workflow process using a set of applications: MS InfoPath Filler, MS SharePoint, MS Sharepoint Form Services, MS Outlook, MS Exchange and MS SharePoint Excel Services.

Step 8 – monitor transaction specification

A form was developed to monitor transaction specifications, as shown in Figure 10.

Ongoing monitoring of transaction specifications is important from a continuous improvement perspective. The form allows proposed improvements to be captured and records performance assessments for the transaction.

Step - 6 Review Transaction Map and Message Template														
General Admin Information														
Name of TM														
Date Reviewed														
Change Log														
Technical Information														
Summary Information:														
Review of To-be Tranasaction Map NOTE: Apply "√" for Yes and "x" for No in the change required column														
Name of Atomic Transaction	Change Req.	Description of Proposed Changes, if any.												
Review of Message Templates NOTE: Apply "√" for Compliance, "x" Non-Compliance, and "-" for Not Applicable														
Name of Atomic Transaction	Sender Role	Receiver Role	Formatting Req.	Context Req.										
	From	To	Design Req.	Location Req.	Contractual Req.	Exchange Req.	Regulatory Req.	Security Req.	To-be Transaction Performance	Others; if any.				
Proposed Changes/Revisions, if any.														

Figure 9.
Review To-be transaction map and MTs – sample form

Step - 8 MonitorTransaction Agreement - (Transaction Map and Message Templates)										
General Administrative Information										
Name of TM										
Date Monitored										
Technical Information										
Summary of Proposed Improvements:										
Monitor Tranasaction Map NOTE: Apply "√" for Yes and "x" for No under Improvement Required Column										
Name of Atomic Transaction	Imrovement Requirement	Description of Proposed Improvement, if any.								
Monitor To-be Transaction Performance (NOTE: Rating criteria is "H" for High, "M" for Medium, "L" for Low, and "N" for Non or Not at All Easy or Not Applicable)										
Time (person-hrs)	Rating	Cost ($)	Rating	Quality	Rating					
Transaction formulation time		Transaction formulation cost		Ease of handling						
Transaction transmission time		Transaction transmission cost		Add other, if any						
Add other, if any		Add other, if any								
Monitor Message Templates (NOTE: Apply "√" for Compliance, "x" Non-Compliance, and "-" for Not Applicable under the Formatting & Context Req. Columns)										
Name of Atomic Transaction	Sender	Receiver	Formatting Req.	Context Requirement						
	From	To	Design Req.	Location Req.	Contrac-tual Req.	Exchange Req.	Regulatory Req.	Security Req.	Others; If any.	
Monitor Message Template Performance (NOTE: Rating criteria is "H" for High, "M" for Medium, "L" for Low, and "N" for Non or Not at All Easy or Not Applicable										
Time (person-hrs)	Rating	Cost ($)	Rating	Quality	Rating					
Message formulation time		Message formulation cost		Ease of handling and navigation						
Message transmission time		Message transmission cost		Ease of tracking and retreival						
Add other, if any		Add other, if any		Add other, if any						
Description of Proposed Improvements for message templates, if any.										

Figure 10.
Monitor transaction specification – sample form

Transaction formalism protocol tool application in the domain of infrastructure management

The TFP Tool was applied in the area of infrastructure management through formalising the capital asset reporting transaction. While formalising the capital asset reporting process, all forms of the proposed TFP Tool were filled using a case study and expert interview approaches. As part of the transaction specification, the complete set of forms was filled for Step 1 (assess needs), Step 2 (define As-is TM), Step 3 (develop To-be TM), Step 4 (collect information) and Step 6 (review TM/MT). The form developed for Step 8 (monitor transaction specification) (Figure 9) was not yet filled because it will be used after implementing the capital asset reporting specification. Some guidance is presented for Step 5 (design MT) and Step 7 (implement TM/MT). In this paper, only the "develop To-be TM form" for the capital asset reporting is presented in Figure 11 as a sample. The To-be TM developed for the capital asset reporting consists of ten atomic transactions; however, only three atomic transactions are shown in Figure 11 because of space constraint. The defined To-be TM for the capital asset reporting was transformed into graphical representation using a UML sequence diagram for clarity and ease of understanding.

The proposed TFP Tool comprises forms developed in MS Excel, which can easily be used by anyone who has some knowledge of Excel. The forms are self-explanatory, and all

Step - 3 Develop To-be Transaction Map									
General Administrative Information									
Name	$tm_{to\text{-}be}$_tca_reporting								
Identifier									
Change Log	**Date (dd/mm/yy)**	**Status**		**E-mail**					
	5/30/2012	Created		xyz@interchange.ubc.ca					
Technical Informtion									
Summary of Proposed Improvements:									
The following is a brief summary of the improvements proposed to the As-is TM. i. **Process improvement** - the As-is communication process is to be modified for some transactions to tranform it from one/two action with no acknowledgement to one/two action with acknowledgement transactions. ii. **Information improvement** - it is proposed that the TCA information is to be defined and well structured in a message form as part of the atomic transaction so that it can be interpretable by the receiving system. iii. **Mode improvements** - current modes of communication adopted for TCA information is to be transformed with an efficient and effective mode of communication - message template based exchange of information through a web-based system.								
To-be Transaction Map Specification									
Name of Atomic Transaction		**From**		**To**		**Proposed Improvements**			
Generic Name	**Specific Name**	**Designation**	**Organization**	**Designation**	**Organization**	**Process Improv.**	**Infor. Improv.**	**Mode Improv.**	**Description of Proposed Improv.**
request tca information	$tm_{to\text{-}be}$_tca_atom$_1$_ request_tca info.	Mgr. Finance	Municipality	Mgr. Engg.	Municipality		√	√	Information is to be defined & communication mode is to be changed from E-mail/Server/Tel/ CD/Post-mail to template based exchange.
receipt acknowledgement tca information	$tm_{to\text{-}be}$_tca_atom3_ receipt_ ackow._tca info.	Co-ord. Engg.	Consultant	Mgr. Engg.	Municipality	√	√	√	Ditto In addition to above, process is to be improved.
accept acknowledgement tca information	$tm_{to\text{-}be}$_tca_atom5_ accept_ ackow._tca info.	Mgr. Engg.	Municipality	Co-ord. Engg.	Consultant	√	√	√	Ditto In addition to above, process is to be improved.
receipt acknowledgement tca information	$tm_{to\text{-}be}$_tca_atom10_ receipt_ acknow_tca info.	Asset Co-ord.	Prov. Govt.	Mgr. Finance	Municipality	√	√	√	Ditto In addition to above, process is to be improved.
Graphical Representation									
Two formal sequence diagrams are created in UML for the To-be Transaction Map specification mentioned above using the generic and specifc names from general user and developer perspective.									
To-be Transaction Performance Criteria									
Time (person-hrs)	**Rate**	**Cost ($)**		**Rate**		**Quality**			**Rate**
Transaction formulation time	L	**Transaction formulation cost**		L		**Level of message interpretability**			H
Transaction transmission time	L	**Transaction transmission cost**		L		**Level of message structuring**			H
						Ease of handling, tracking & retrieval			H

Notes: Rating criteria is "H" for high, "M" for medium, "L" for low and "N" for non or not at all easy or not applicable

Figure 11.
Develop To-be TM for asset inventory and condition assessment reporting/capital asset reporting

items represented in the forms are explicitly defined. The transaction specification development starts with identifying and assessing the needs, which is to be done using the "Assess Needs" form. The users will then describe the As-is and To-be transaction maps/communications using the "Define As-is" and "Develop To-be" forms, respectively. Then, the message header and payload information is entered in the "Collect Information" form. Based on the collected information, message templates are designed, which are reviewed for any errors or modifications using the "Review" form. After review, specifications are implemented in a computer-based application so that the required information can be exchanged between the parties efficiently. The implemented transaction is continuously monitored for improvements using the "Monitor Transaction Specification" form.

In this process, the municipal government reports the TCA information to the provincial government for financial planning and budget allocations. Presently, there are some issues with this process:

- The TCA reports are sent as a word or PDF document attached to an e-mail, which needs human interpretation at the receiving end, thus making the whole process prone to errors.

- The TCA reports are generated in different data formats that make it difficult and time-consuming to extract and compile data manually.
- The reports generated from various municipalities differ in definition and grouping of assets into various categories, making interpretation of data difficult.

The proposed TFP Tool was used to formalise the capital asset reporting process, which was implemented in a prototype AIIS, which collects, integrates and analyses the asset information received from different municipalities.

Transaction formalism protocol evaluation

The proposed TFP Tool was validated through industry experts using a framework presented in Table I. The framework shows a set of criteria, measures and tests in terms of the questions. Adesola and Baines (2005) identified three criteria, feasibility, usability and usefulness to validate an improvement methodology, which were adopted with modifications to validate the proposed TFP Tool. An additional criterion – generalisability – was also identified, defined and used to validate the TFP Tool.

Feasibility assesses the Tool appropriateness in terms of completeness, correctness and reasonableness. Usability assesses the ability to learn and work with the Tool and was evaluated using three measures: understandability, applicability and guidance/supportability. Usefulness assesses the utility and value of the Tool in terms of five measures: effectiveness, efficiency, consistency, changeability/adaptability/customisability and reusability. Finally, generalisability assesses applicability of the TFP Tool across a wide variety of communications within the AEC/FM and non-AEC/FM industries, using a single measure of generality. These metrics, measures in terms of the associated questions and average scores against each measure are shown in Table I.

The TFP Tool was validated using an expert interview approach. The TFP Tool was presented to experts through a questionnaire. The experts were transaction analysts, process modellers and industry experts in the domain of infrastructure management. Five experts were selected based on two criteria:

(1) expertise in one of the infrastructure sectors; transportation, water, wastewater and solid waste management in terms of the total number of years ranging from 7 to more than 15 years; and

(2) knowledge of data modelling, transaction design, process modelling, etc.

Respondents having experience in either infrastructure asset management, or data modelling, process modelling and transaction modelling, are equally important; however, the best choice was to select those who have experience in infrastructure management and data, process and transaction modelling. The expert interview composed of three sessions. In the introduction session, the proposed TFP Tool was introduced. In the comprehension session, the form content was understood. In the execution *session,* experts (A, B, C, D and E) examined the forms completed for the capital asset reporting and answered all the questions shown in Table I. All answers were recorded on an agreement continuum rating system: unable to rate (0), strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4) and strongly agree (5).

The expert review data for each of the criteria of feasibility, usability, usefulness and generalisability were recorded against each question (i.e. measure). For instance, the respondents were asked to provide a subjective assessment of the measure – generality. They were asked the question; "Is the proposed TFP applicable to formalise diverse communications in the AEC/FM and non-AEC/FM industries?" Based on this question, their responses were recorded on a continuum scale of 1 (strongly disagree) to 5 (strongly agree), and an average score was calculated

TFP tool evaluation									
			Respondents						
Criteria	Measures	Tests – how to achieve a measure?	A	B	C	D	E	Agreement Ratings	Average Score
Feasibility	Completeness	Does the TFP tool incorporate all the steps required for the design/improvement, implementation, and management of transactions?	5	4	4	5	4		4.4
	Correctness	Are the steps of the TFP tool right?	5	4	5	5	4		4.6
	Reasonableness	Are the steps of the TFP tool reasonable?	5	5	5	4	5		4.8
Usability	Understandability	Is the TFP tool easy to understand?	5	4	5	5	5		4.8
	Applicability	Is the TFP tool easy to apply while defining transactions?	5	4	4	5	4		4.4
	Guidance/supportability	Does the TFP tool provide sufficient guidance on how to fill various sections of forms?	5	4	4	5	5		4.6
Usefulness	Effectiveness	Do you feel that the use of the TFP tool produce useful and effective results?	4	5	4	5	4		4.4
	Efficiency	Does the use of the TFP tool save you time and cost compared to defining transactions without using the proposed TFP tool?	5	4	5	4	5		4.6
	Consistency	Does the use of the TFP tool result in the creation of consistent transactions that are easily implementable in a variety of applications?	5	4	5	5	3		4.4
	Changeability/adaptability	Does the use of the TFP tool result in the creation of transactions that are easily modifiable with changing requirements?	4	3	5	5	3		4
	Reusability	Does the use of the TFP tool result in the creation/development of reuseable transactions?	4	4	5	5	5		4.6
Generalisability	Generality	Is the proposed TFP applicable to formalize diverse communications in the AEC/FM and non-AEC/FM industries?	4	5	5	4	4		4.4

Table I.
TFP tool validation

as shown in Table I. For both the feasibility and usability, the average scores ranged from 4.4 to 4.8, whereas for usefulness, the average score varied between 4 and 4.6. Similarly, for generalisability, the average score was 4.4. Comparing the average scores of various criteria, it was found that the feasibility and usability scores were higher than usefulness and generalisability scores. The lowest average score for usefulness criteria was due to lower score recorded for adaptability/changeability measure, which is attributed to respondent's least farsightedness about the dynamic future requirements of the already defined transaction specifications. Within a specific criteria, the average score was varied, which is attributed to following reasons:

- subjective assessment of the respondents – different individuals have different responses;
- cognition level – different people have different thought levels;
- related expertise in the domain of interest; and
- explicit knowledge of the respondents.

Although there were differences in the individual average scores, the resulting average scores ranged from 4 (agree) to 4.8 (strongly agree), indicating that the respondents were in general agreement on the feasibility, usability, usefulness and generalisability of the proposed TFP Tool.

Conclusions

In the area of infrastructure management, there is a growing trend to transform the current practice of manual data exchange to a more formalised computer-to-computer data exchange (transaction). How to formalise these transactions for computer-based collaboration is the core research question. Presently, some methodologies and standards do exist, but they do not fully support the design, implementation and management of transactions. These standards are mostly process-centric and support 3D-object-based data exchange in comparison to message-based exchange of information required for computer-based collaborations. Also, existing methodologies lack a step-by-step procedure that the transaction development personnel can easily apply. These issues emphasise on the need to develop a step-by-step procedure – the proposed TFP to formalise transactions for computer-based exchange of information using standardised message templates. A five-step research methodology was devised to develop the proposed protocol: identify and select candidate standards (Step 1); benchmark existing standards (Step 2); link and build on existing standards (Step 3); develop the TFP (Step 4); and validate the protocol (Step 5).

The proposed protocol is a step-by-step procedure consisting of eight steps developed from two perspectives: the TFP Specification and TFP Tool. The TFP specification represents a conceptual framework treating each step as a distinct function for which inputs, controls, mechanisms, Tool/techniques and outputs were defined. On the other hand, the TFP Tool was created from the application perspective that consists of a set of Excel-based forms and guidance developed for each step of the protocol. This paper introduces the TFP Specification and discusses the detailed development of the proposed TFP Tool. The eight-steps of the proposed protocol are assess needs, define As-is TM, develop To-be TM, collect information, design MTs, review TMs and MTs (transaction specification), implement the transaction specification and monitor transaction specification for continuous improvements. Excel-based forms were developed for all steps except Steps 5 and 7 for which detailed guidelines were developed on how to perform them. The proposed Tool addresses the shortcomings of the existing standards and methodologies used for transaction formalisation.

The TFP Tool was applied to formalise the capital asset reporting in which the municipal government sends the TCA information to the provincial government for financial planning and budget allocation. This transaction was selected from a prioritised list developed as a result of an ICT survey conducted as part of this research work in the area of infrastructure management and was implemented in a prototype system – AIIS (beyond the scope of this paper) – to enable municipalities to report their TCA information to provincial government effectively and efficiently.

The TFP Tool was validated using four criteria: feasibility, usability, usefulness and generalisability. The validation results indicated that the Tool was feasible, usable, useful and generic. The development of the proposed Tool has practical contributions by enabling transaction development personnel to develop transaction specifications effectively and efficiently for implementation in applications. The limitations of the proposed Tool include the following points:

- *Use of personnel*: Depending upon the information requirements and expertise of the personnel using the proposed Tool, in some cases, two or more individuals would be required to formalise a transaction.
- *Semi-automated process*: In its current form, the transaction formalisation is performed semi-automatically using a set of Excel-based forms.
- *Online support*: Because of semi-automated nature of the proposed Tool, presently, online support is not available.

It is recommended that the proposed Tool needs to be further tested to formalise diverse communications in various application domains or industries to monitor its validity and generalisation. The complete transaction formalisation cycle duration also needs to be explored and examined to objectively check effectiveness and efficiency of the proposed Tool. For quantitative assessment of the protocol in terms of the time gained and errors avoided, the Tool needs to be applied to several other projects in the area of infrastructure management. In addition, a framework of transaction maturity needs to be developed to embed the transaction development personnel skills into the protocol to reflect skill and knowledge competence. This would help in tailoring user's skill sets with each step of the TFP Tool. Moreover, it would be more beneficial if the proposed TFP Tool is to be implemented in an interactive Web-based application. This would help in creating transaction specifications automatically while also improving self-learning and communication between the transaction development personnel. Availability of the proposed TFP Tool to practitioners is subject to further refinement and implementation into a semi-automated Web-based application.

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