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SURVEY OF INFORMATION TECHNOLOGY USE FOR MUNICIPAL INFRASTRUCTURE MANAGEMENT

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SUMMARY: *As municipalities increasingly rely on computer-based systems and data management, information that was traditionally exchanged through human communications can now be exchanged electronically through computer-to-computer data exchange. This requires much more formal specifications and agreements to govern these data exchanges. The main purpose of the paper is to identify the current state of information technology use in the municipal infrastructure management through benchmarking: (i) a range of information technology systems used to accomplish various work processes; (ii) and a range of communication channels used to exchange information between various parties. A combination of web and face-to-face interviews was used, and the results of the survey show that municipalities are equipped with a variety of information systems that can readily manage asset infrastructure systems, yet the way information is exchanged between various parties is still conducted in an unstructured and ad hoc way.*

KEYWORDS: *Infrastructure Management, Communication Channel, Benchmark, Transaction, IT Use*

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1. INTRODUCTION

Society relies on its public infrastructure systems—roads, water systems, waste systems, etc. These are large, complex systems owned and operated by municipalities and other infrastructure agencies. Our focus is on the information technology (IT) that agencies use to manage their infrastructure systems and, in particular, on the ways that information from these systems can be exchanged between organizations. As municipalities increasingly rely on computer-based systems to manage infrastructure data, much of the information that was traditionally exchanged through human-communications can now be exchanged electronically through computer-to-computer data exchange. This allows for more extensive, rapid, and error-free exchange of information, but it requires more formal specifications and agreements to govern these data exchanges. Examples of information exchange between infrastructure organizations or between infrastructure management systems include communications during disaster response (Is power available in this area? Who is responsible for this section of roadway? When will water be restored to this area?); coordinating between buried utility agencies to provide a “call-before-you-dig” call center for excavations; or aggregating data from multiple infrastructure management software for the purpose of performing sustainability analysis or reporting to meet public sector accounting requirements.

Formalizing infrastructure transactions in order to support computer-to-computer information exchange involves three issues: "how to formalize", "why to formalize", and "what to formalize". Elsewhere, we are exploring the first issue through the development of ontologies of infrastructure systems and communications. This paper addresses the second and third issue through an industry IT survey. The objectives of the survey are:

1. *Benchmark IT Systems* – benchmarks the range of IT systems to identify the current state of IT use across municipalities in British Columbia (BC).
2. *Benchmark Communication Channels* – benchmarks the range of communication channels to provide insights on how municipal organizations exchange asset information. This serves as input to the development of improved methods for formalizing and specifying data exchange agreements used to support automated/semi-automated systems.
3. *Transaction Identification* – identifies the transactions that have the greatest potential for IT improvement.
4. *Municipality IT Evaluation* - allows participating municipalities to evaluate their level of IT use in comparison with the current best practices.

To achieve these objectives, the following three activities were carried out using a combination of web-based and researcher-administered interview survey approach:

1. *Investigate the use of IT for municipal infrastructure management:* This activity benchmarks the types of software used at the municipality level and at the engineering services/public works department level for various infrastructure management processes. The survey: (a) categorizes and ranks the general work processes that use IT; (b) categorizes and ranks the type of IT systems or computer applications used to accomplish these work processes; (c) categorizes and ranks computer applications that the department of engineering/public works use for asset management, and (d) examines the level of interoperability of these IT systems within and across municipalities with other organizations that own or operate similar infrastructure information systems.
2. *Investigate the use of IT for transactions within and between municipalities*. This activity concentrates on the communications channels being used to accomplish transactions and to identify transactions that have the potential for significant improvement. The survey: (a) identifies various communication channels used for transactions at the municipality level; (b) identifies various communication channels that the department of engineering/public works use for the exchange of asset information.
3. *Investigate methodologies for transaction design and improvement.* This activity investigates transaction design methodologies. The survey: (a) examines the requirement for a methodology that experts can use to design transactions; and (b) identifies the transactions that have the greatest potential for IT improvement.

The use of IT was examined at two levels: (i) the municipality level – to capture the use of IT within different disciplines of the municipality; and (ii) the engineering services/public works department level – to capture the use of IT for infrastructure management with a focus on water, wastewater and road infrastructure systems. At the department level, the use of IT was examined for the asset maintenance management planning work function.

The scope of this paper encompasses the results of the survey relating to the use of IT in the area of municipal infrastructure management. The paper first discusses related research work, then describes the survey research methodology, followed by the survey results and discussion.

2. RELATED RESEARCH WORK

2.1 Global context

In the past decade, several surveys around the globe have been carried out to benchmark IT usage in the AEC/FM industry. The IT Barometer Series is a longitudinal survey conducted in the Nordic (Sweden, Denmark, and Finland) construction industry at different times to compare the results and benchmark IT usage in the three core areas: projects webs, CAD, and electronic trade. It also provides knowledge of communication tools and access to computers along with a future road map of IT in the Nordic construction industry (Howard and Samuelson, 1998; Samuelson, 2002; and Samuelson, 2008). A similar IT survey has been conducted for the Singapore construction industry and its results were compared with the Nordic IT Barometer Series surveys. The focus of this survey was to check the general level of IT usage and specific adoption of IT originated from the CORENET, an IT development program started for the Singapore construction industry (Hua, 2005). A modified version of the Barometer survey was conducted for the Jordanian AEC industry (El-Mashaleh, 2007). Moreover, computer usage for core functional areas were benchmarked for the New Zealand's building and construction industry (Dohert, 1997) and the state of internet use was surveyed in the Malaysian construction industry by (Mui et al., 2002).

The state of the IT in the Nigerian construction industry was explored to benchmark the level of adoption, its overall impact on the industry and barriers towards its adoption (Oladapo, 2007) while (Scheer et al., 2007) investigated IT application experiences in the Brazalian AEC industry. In Turkey, one survey focused on the current and planned IT use for the acquisition of building product information on the supply (manufacturer & supplier) and demand side (architect), and identified methods and reasons for providing and receiving building product information (Tas and Irlayici, 2007). A second survey was conducted from two perspectives: the industrial and academic. The industrial theme investigated the strategic role of ICT implementations in the AEC industry and the academic theme explored the future road map for construction informatics, which encompasses the following areas: strategic ICT management, integration, and interoperability of organizations and their information systems (Isikdag, 2009). (Love et al., 2004) investigated IT investment in the small and medium enterprises (SMEs) in the Australian Construction Industry, while (Tse and Choy, 2005) explored IT usage in the quantity surveying organizations of the Hong Kong construction industry.

From the results of these studies, it can be seen that the construction industry is making use of standalone computer applications to undertake various construction processes. Due to the propriety nature of these applications, there exists the problem of interoperability between these applications. The use of internet is common for the exchange of information (information transactions) but this is largely limited to e-mail and downloading of documents posted on web sites. Transaction agreements in the construction supply-chain organizations are relatively formalized and electronic trade of building products is quite common. These studies have identified the road maps for construction IT implementation, but due to its fragmented nature, multiplicity of stakeholders, and short project durations, the construction industry is still lagging behind other industries such as manufacturing, pharmaceutical, electronic, etc.

2.2 North American context

Various surveys have investigated the state of IT and its impact on the North American construction industry. In the United States of America (USA), the Construction Financial Management Association (CFMA, 2008) conducts an IT survey for the construction industry every two years to benchmark systems, software, and solutions used by the construction organizations. Moreover, (Issa et al., 2003) investigated the level of e-business implementation within the project management systems of the general contractors in the US Construction Industry.

In Canada, (Rivard, 2000) conducted a survey to assess the impact of information technology in the Canadian AEC industry. Rivard et al. (2004) investigated 11 case studies across Canada to define best practices in the use of IT in the AEC industry. At the University of Alberta, (El-Ghandour and Al-Hussein, 2004) have undertaken a survey to benchmark research published in 12 scientific journals between 1992 and 2001 in the field of Information Technology in Construction (ITC). They have analysed nine ITC tools against 43 application areas. In addition, (Froese and Han, 2005) investigated the state of companies developing information technology for the construction industry in Canada.

The core thrust of these global and North American surveys was to investigate and identify the usage and impact of IT, barriers to its implementation and future direction of IT in the construction industry from the perspective of architectural, engineering, and contractor organizations. IT surveys from the local or municipal government perspective have rarely been conducted, specifically with regards to infrastructure asset management. The importance of this niche segment (municipal/local government) of the construction industry can better be judged through: (i) municipal or local government is managing 20% of the Canadian civil infrastructure portfolio valued at $5.5 trillion in 1999 constant dollars, (Vanier and Rahman, 2004), which is around $1.1 trillion; (ii) around 90% of the Canadian population is served by the municipalities; and (iii) as public organizations, municipalities have to ensure efficient utilization of the public money.

3. SURVEY RESEARCH METHODOLOGY

3.1 Phase 1 – survey planning

Respondents were selected to be experts from local and regional governments (municipalities, in the province of British Columbia). Municipalities were categorized into four types based on the size of area and population: City, District, Town and Village. With respect to IT, the scope focussed on general IT use for work processes such as financial management, accounting, human resource management, procurement, work order management, environmental management, progress tracking, and property information management. In terms of infrastructure systems, the scope was chosen to be water, wastewater and transportation systems. Finally, the scope was further constrained to the asset management work functions. For the selection of a data collection mode, because of the relatively technical and complex nature of some of the research questions and the relatively small number of respondents expected, a combination of the initial web-based survey followed up with a researcher-administered face-to-face structured interview survey was chosen. According to (Glastonbury and MacKean, 1991), interviews offer the flexibility to reach into the respondent's situation, probe for more detail, seek more reflective replies, and ask questions that may be more complex or personally intrusive. According to (Lindlof and Taylor, 2002) structured interviews are the best suited for focus group studies.

3.2 Phase 2 – survey design

The questionnaire was divided into 3 parts containing a total of 8 sections: (i) Part A, Section 1, general information about the respondents organizations and infrastructure systems; (ii) Part B, Sections 2 through 5, benchmarking IT use in Infrastructure Asset Management; and (iii) Part C, Sections 6 through 8, examination of the methodology used to identify and define IT-based communication processes. Part A was a web-based questionnaire completed by respondents on-line, whereas Parts B and C were paper questionnaires completed by the interviewer during the face-to-face interviews. A fictitious data set was generated based on expected responses and used to develop the result tables and analysis that would be carried out on the actual survey data. This also helped to further refine the questionnaire. A data visualization strategy was also developed in this step. The survey methodology and questionnaire underwent an ethics review, which included protocols for invitation and approval processes, data confidentiality, etc. Next, the questionnaire was subjected to alpha and beta testing. Alpha testing involved a preliminary round of having people that were not involved in the questionnaire development complete the draft questionnaire in order to assess the degree to which the questions were understood by respondents and the degree to which the questions solicited the expected information from respondents. This led to further refinements to the questionnaire. Beta testing involved conducting an initial round of actual interviews with a small number of the respondents from the target study group, after which final adjustments were made to the questionnaire that was then finalized and used for the full-scale study.

3.3 Phase 3 – survey execution

The first step in conducting the survey was to identify the target sample, or intended respondents. A sample refers to a part of the population that is representative of the entire data/population being studied, (CSU, 2009). According to (Ader et al., 2008), three advantages of sampling are; (i) cost reduction; (ii) faster data collection; and (iii) enhance accuracy and quality of data due to smaller size. For this study, a stratified sampling approach was used in which the entire population (all BC municipalities) was divided into smaller units or strata based on their size and type, from which samples were chosen. This approach improves the ability to analyse individual stratum separately, compare the strata effectively, and correlate variables of interest. The population for this research work was the set of municipalities in south-western British Columbia, Canada (within a practical and economic travelling distance for the researchers to carry out face-to-face interviews). This population was divided into 4 strata: 23 city municipalities (population greater than 5000), 22 district municipalities (area greater than 800 hectares with population densities less than 5 people per hectare), 08 town municipalities (populations between 2500 and 5000), and 5 village municipalities (population less than 2500).Within these 46 municipalities, a total of 114 individuals were ultimately contacted personally and invited to participate. Due to lack of response, both the Town and Village municipalities were dropped from the study, and the scope was re-focussed on the larger city and district municipalities alone, which were, in any event, expected to yield the more advanced best practices for use of IT. The survey sample and response profile is shown in Table 1.

TABLE 1. Survey sample and response profile

Type of Municipality	Municipalities Contacted	Municipalities Responded
City Municipalities, (Population > 5000)	15	8 (53%)
District Municipalities, (Area > 800 Hectare and Pop Density < 5 Pop/Hectare)	18	4 (22%)
Town Municipalities, (Population ≥2500 ≤ 5000)	8	0 (0%)
Village Municipalities, (Population < 2500)	5	0 (0%)
Total	**46**	**12 (26%)**

In response to invitations sent via e-mail to each municipality (on average, 3 people were contacted for each city and district municipality), the survey participation request was accepted from 8 cities, 4 districts, and no towns or villages. A single person only was interviewed from each municipality that participated. Upon receipt of their willingness to participate in the survey, the research background information, consent form and questionnaire were sent to them, along with a request to complete part A of the questionnaire on-line (5 questions, requiring approximately 20 to 30 minutes). Later, a face-to-face interview was scheduled with the respondents to complete Part B (12 questions) and Part C (13 questions) of the questionnaire for a total duration of 1 to 1.5 hrs.

3.4 Phases 4 and 5 – survey analysis and reporting

The raw survey data was collected into summary tables and charts, and this processed data was analyzed as discussed in the subsequent sections. The final step in conducting the survey (to be completed) is the reporting of the results back to the municipalities and other interested parties.

4. SURVEY RESULTS AND DISCUSSION

4.1 Municipality profile information

The general profile information collected describes municipality demographics and profile in terms of full-time equivalent employees and infrastructure systems characteristics. The demographic profile of the municipalities shows the population served (Fig. 1). This demonstrates a broad range of population sizes for both cities and districts, from a city of 472,000 people to a district of 2,000 people, and thus the survey spans a wide spectrum in the sizes of municipalities for which we are investigating the IT practices.

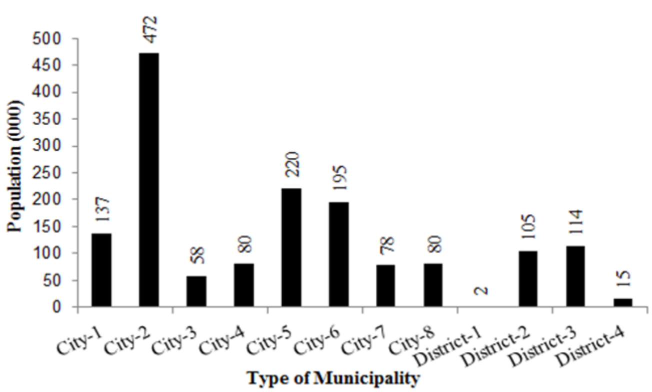


FIG. 1: Municipality populations

The Fig. 2 shows the respondents' Full Time Employees (FTEs), both the total municipal employees and technical employees working in the engineering services/public works department. The total municipal FTEs range from a minimum of 6 to a maximum of 1,800, while the engineering services department FTEs range from 1 to 187 (representing between 1% to 22% of the total number of municipal employees). Again, this represents a wide range of municipal employee sizes.

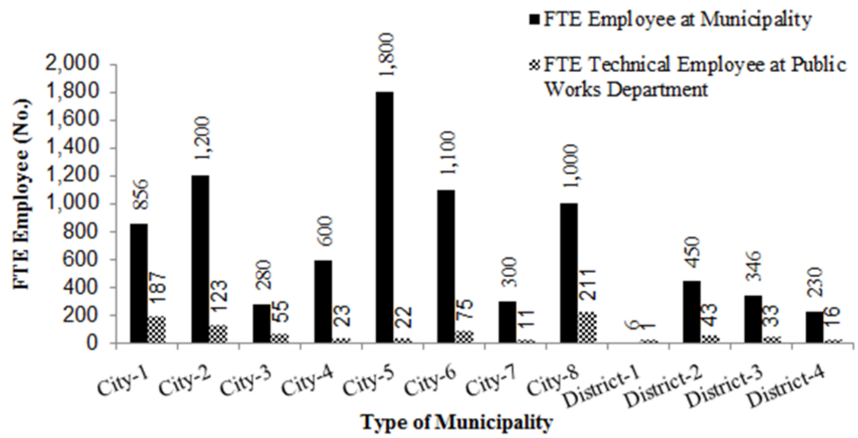


FIG. 2: Municipal employee counts

The Fig. 3 shows the quantity of municipal infrastructure assets expressed as the total length of the water, wastewater and road networks. In district municipalities, some infrastructure systems are reported as zero since the municipality doesn't own or operate these systems (e.g., the water supply is well-based and wastewater/sanitation is septic tank-based, both privately owned by residents, or the road network is managed by the Ministry of Transportation).

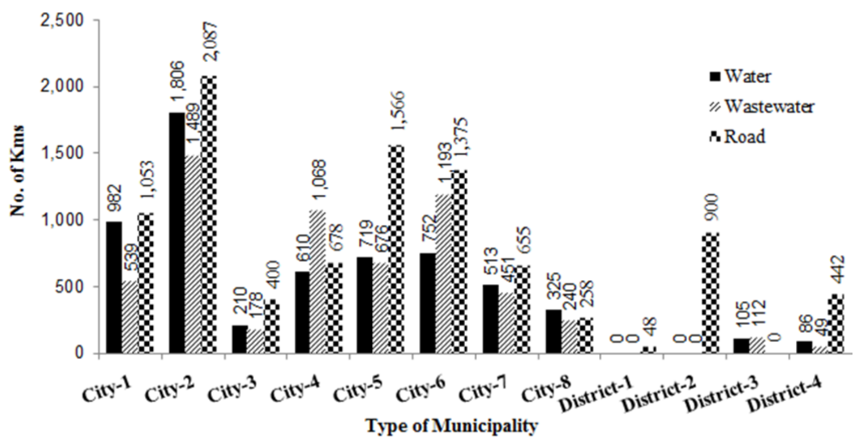


FIG. 3: Asset infrastructure systems profile

These results show a very great spread in the relative number of technical employees responsible for the municipal infrastructure systems—ranging from 0.1 to 2.6 FTE per 1000 population and ranging from 7 to 256 FTE per 1000 km of infrastructure. These differences are not simply a function of population; rather the different levels of relative technical resources are distributed across the different sizes of municipalities. Possible reasons for these variations include different outsourcing strategies (some municipalities employ in-house professionals for much of their design, construction, and maintenance work, while others work mostly through hired consultants), the issue of understaffing in some municipalities, or possibly errors in the self-reporting of this profile data from the survey respondents.

Based on the self-reported data about IT skills and systems, all of the technical FTEs working in the engineering services departments are computer literate with varying degree of IT operational skills. All of the city municipalities have acquired current IT technologies to manage their infrastructure systems (as described in the following sections), but many of the municipalities rely on consultants for IT systems relating to the design and modelling of infrastructure systems.

4.2 Benchmarking IT use

IT use was benchmarked at two levels: (i) general IT use to support infrastructure management throughout the municipality, and (ii) IT use for specific infrastructure management functions within the engineering department.

4.2.1 General IT use throughout the municipality

Respondents were asked to list the software used at the municipality level to manage infrastructure systems and to identify the processes accomplished with this software. Processes recorded were then grouped into five categories; planning and scheduling, design, finance and accounting, management, and monitoring. The software reported for the first three categories of processes are listed in Table 2 and for the last two categories in Table 3. While each software system may support many different functions and processes, those listed in Tables 2 and 3 are the ones reported by respondents during the face-to-face interviews. These work processes were carried out by the engineering, planning, utility, operation, finance, and administration departments of the municipalities. Most of the design work is entrusted to consultants; therefore, the use of the CAD software was limited only to modifications of the infrastructure network models prepared by the consultants. Similarly, the planning software is mostly used for program and portfolio management. Most of the municipalities were using up-to-date versions of the software, but some reported using older versions that were in need of upgrading.

TABLE 2. Software versus planning and scheduling, design, and finance and accounting processes

	Processes								
	Planning & Scheduling		**Design**	**Finance and Accounting**					
Software	Project Planning/ Scheduling	Land use Planning/ Zoning	Design/ Analysis of Asset	Financial Reporting	Financial Planning/ Budgeting	Physical/Financial Progress Tracking	Financial Record Keeping of Asset	Accounting	O&M Costing of Assets
Excel	x								
ESRI-ArcGIS		x		x					
SAP				x	x			x	
MS Project	x					x			
AutoCAD			x						
CityWorks									x
Maximo						x			
Tempest								x	
CAMPA							x		
iCity				x	x		x	x	
Agresso				x	x			x	
WaterCAD			x						
SewerCAD			x						
StormCAD			x						
Infowater			x						
InfoSewer			x						
Mike Urban			x						
PeopleSoft				x	x			x	
Cayenta				x	x			x	

TABLE 3. Software versus management and monitoring processes

Software	Processes							
	Management					Monitoring		
	Human Resource Management	Procurement/Work Order Management	Project, Program, Portfolio Management	Environmental Management	Property Information Management	Operations Monitoring/ Reporting	Approval Process Tracking & Inspection Reporting	Spatial Data Viewing and Mapping
SAP	x	x			x			
MS Project			x					
COSMOS								x
CityWorks		x						
Maximo		x						
Tempest					x			
PTS			x					
WebWorks		x						
FlowWorks						x		
EMS				x				
ESRI-Cityview							x	
iCity	x				x			
ESRI-Arcview								x
FME								x
IFIX						x		
Mapguide								x
Agresso	x	x						
Geosource								x
PeopleSoft	x	x			x			
Amanda							x	
Cayenta	x	x			x			
Iconics						x		
MapInfo								x
Geocortex								x

4.2.2 Specific IT use within the engineering/public works department

IT use was assessed within the Engineering/Public Works Departments for the Asset Maintenance Management Planning Work Function (AMMP-WF), a meta-level work process within the domain of infrastructure management to asses, analyze, and select the maintenance and rehabilitation alternatives. (Vanier et al., 2006) have identified and defined six sub-processes of the AMMP-WF: (i) asset inventory management; (ii) asset condition assessment; (iii) asset service life analysis; (iv) asset life cycle cost analysis; (v) asset risk analysis; and (vi) decision making analysis. Respondents were asked to record the software used for each of these sub-processes, as shown in Fig. 4. The x-axis shows different software that the municipalities use to perform various work functions, the vertical axis shows the percentage of municipalities that report using each software for the indicated work function, and z-axis represents sub-processes of the AMMP work function.

Of the six processes, the highest software use was for asset inventory management of water, wastewater, and road infrastructure. All 12 municipalities (100%) reported using software to support this work function, and they reported using a total 12 different software tools, with the most common software being ArcGIS, which was used by 83% of the municipalities. The authors identify three possible reasons for this level of computer support: (i) the importance of the process as a range of stakeholders from citizens to management staff require timely and accurate inventory information in order to perform various processes; (ii) the need for effective and efficient ways to store and retrieve a large set of asset information; and (iii) Canadian legislation related to the Public Sector Accounting Board Standard PSAB-1350 has recently required Canadian municipalities to report their infrastructure assets in a consistent manner, which has prompted municipalities to address the issue of formalizing their infrastructure inventory management. The second highest level of software support was for asset condition assessment, with 67% of municipalities using at least one of 8 different software tools (the most common software, dTIM was used by 25% of municipalities); 58% of municipalities used at least one of 6 different software tools for Asset Life Cycle Cost Analysis; 50% used one of 5 different software tools for Asset Service Life Analysis; 50% used one of 3 different software tools for Decision Making Analysis; and no one reported the use of any software tools for asset risk analysis, possibly because any risk analysis carried out was completed by consultants who performed most of the modelling and design of municipal infrastructure projects.

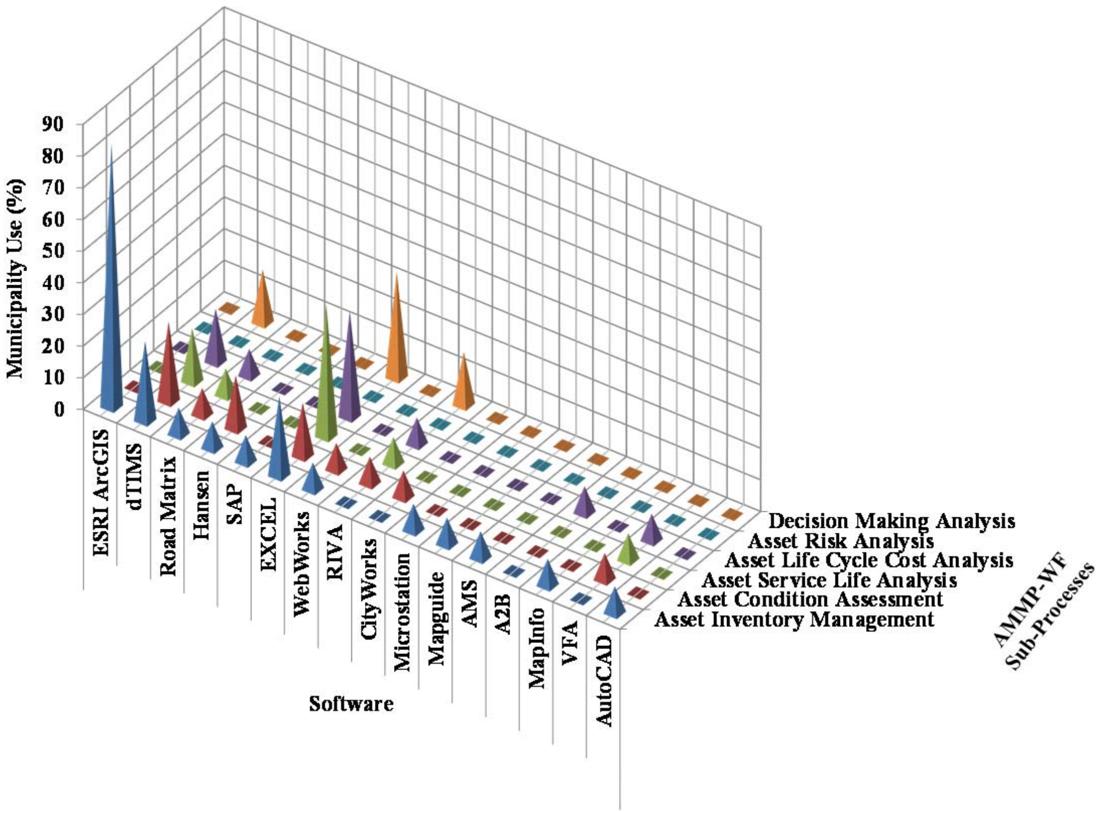


FIG. 4: Software versus asset maintenance management planning work function (AMMP WF)

Sixteen different software systems are currently in use to manage different infrastructure systems in the surveyed city and district municipalities. Across all of the work functions carried out by all of the municipalities, the most commonly used software tool is Excel, followed by dTIM and then ArcGIS. The common use of Excel is due to its suitability, convenience, and pervasiveness for carrying out general technical calculations and data management, which are often sufficient for asset management processes. The use of the dTIMs was slightly higher than the ESRI Arc-GIS across the six sub-processes because most of the municipalities use dTIMs to accomplish most asset management processes, whereas ESRI Arc-GIS use was limited to asset inventory management only (for which most municipalities (83%) have installed ESRI Arc-GIS to deal with the largely GIS-based inventory data). The results indicating the different levels of software use across different municipalities and different work functions were found to be statistically significant using an ANOVA two-factor without replication technique, where the value of "F" was greater than "F_{crit}" (2.08>1.72) with p-value 0.00036 less than the alpha factor 0.050, indicating that the null hypothesis (no statistical difference between the degree of software use) is to be rejected and there was a significant difference between the use of these software applications to perform the six work processes of the AMMP work function.

Moreover, the use of different software in the city and district municipalities is presented in Fig. 5. The x-axis represents various types of software; y-axis shows the percentage of the municipalities that use different software applications for the six work processes of the AMMP work function, and z-axis shows different types of municipalities.

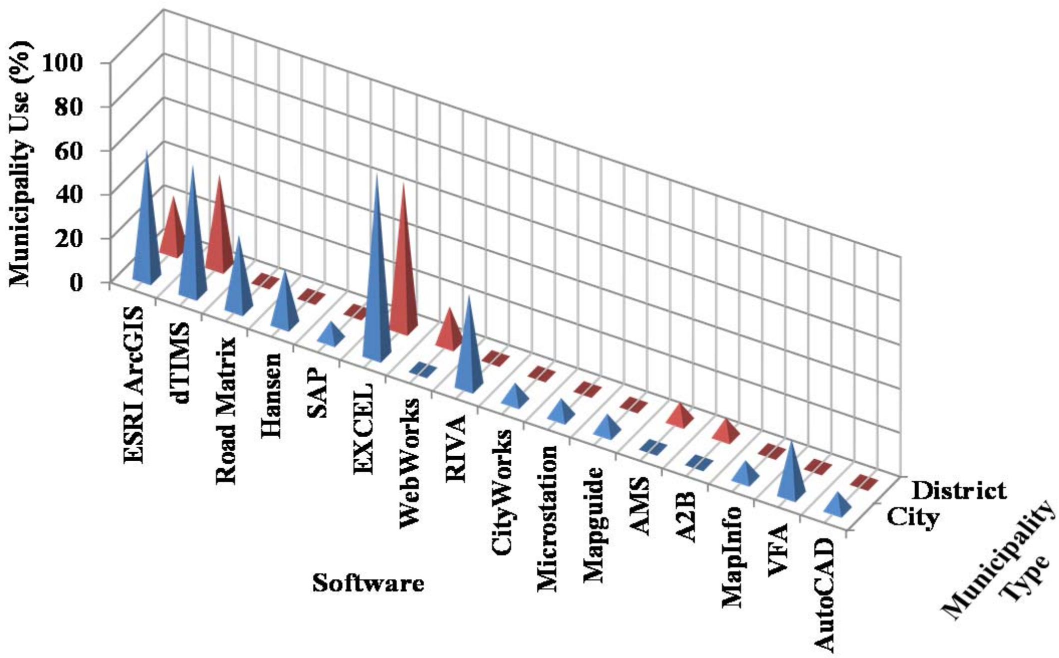


FIG. 5: Software use in the city and district municipalities

Results indicate different levels of software use at the city and district municipalities, which was found to be statistically significant using an ANOVA two-factor without replication technique, where the value of "F" was greater than "F_{crit}" (10.47>4.54) with p-value 0.0055 less than the alpha factor 0.050, indicating that the null hypothesis is to be rejected and there was a significant difference between the use of these software in the city and district municipalities. The null hypothesis states that there is no statistical difference between the use of different software applications in the city and district municipalities to perform six work processes of the AMMP work function. The potential reasons for these differences include greater financial resources, human resources, and availability of required technical skills within city municipalities.

Figures 5 and 6 show a set of software that are currently in use by different municipalities to manage their infrastructure systems. These software applications can be grouped into two categories: general purpose and specific purpose software as shown in Table 4. *General purpose software* performs a variety of general functions in addition to performing specific engineering or technical functions (e.g., Excel), whereas *specific purpose software* are intended to perform specific engineering or technical functions (e.g., dTIMS, Hansen, RIVA, etc.).

4.2.3 Infrastructure information systems interoperability

To manage infrastructure systems, municipalities use a variety of software applications as described above. This section explores interoperability among these systems. According to Osman and El-Diraby (2006), interoperability is the ability for information systems to communicate with each other in a collaborative environment. It has two types: data interoperability and information interoperability. In data interoperability, different information systems can exchange data but cannot interpret the meaning of the data, whereas in information interoperability, different information systems can exchange data and also have the capability to interpret the meaning of the data content. Data interoperability has more of a flavour of "data reporting", while information interoperability comes closer to the concept of truly integrated systems.

TABLE 4. Software categorization based on general and specific purpose

Software Applications	Purpose			
	General Purpose	Specific Purpose		
		Infrastructure Management	Database	Design/ Drafting
ESRI-ArcGIS		x		
dTIMS		x		
RoadMatrix		x		
Hansen		x		
SAP		x		
Excel	x	x		
WebWorks		x		
RIVA		x		
CityWorks		x		
Microstation		x	x	
Mapguide		x	x	
AMS		x		
A2B		x		
MapInfo		x		
VFA		x		
AutoCAD		x		x

Infrastructure information systems interoperability was assessed both "within" different disciplines of a single municipality and "between" different municipalities, for both the data and the information levels as shown in Fig. 6. Within the municipality, 58% respondents recorded data interoperability and 42% recorded information interoperability of their infrastructure information systems, indicating that different systems communicate with each other at different level of interoperability. Between the municipalities, 75% of respondents reported data interoperability and 25% reported information interoperability of the infrastructure information systems. This suggests that there is more data reporting to external entities than to internal ones, while there is more systems integration within the municipality than external to it.

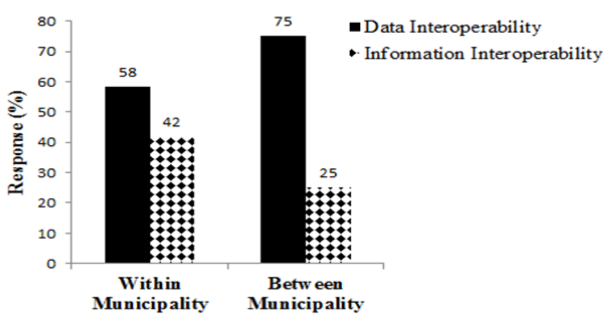
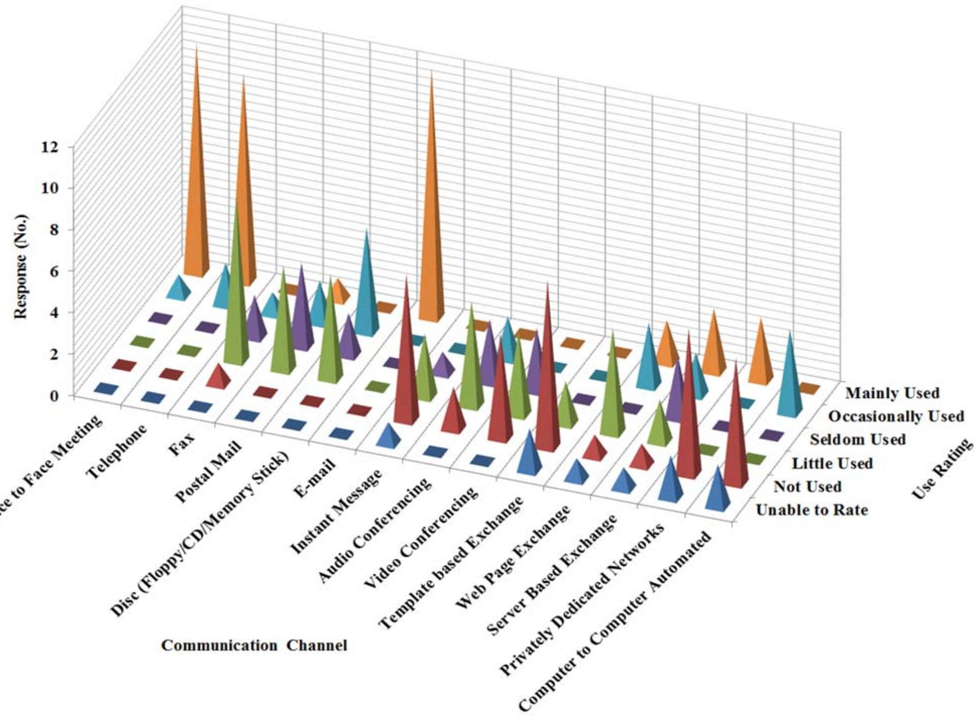


FIG. 6: Interoperability of infrastructure information systems

4.3 Benchmarking communication channels for transactions

To benchmark communication channels, respondents were asked to record various channels they use for the exchange of information at two levels; general use at the municipality level and specific use at the engineering/public works department level. At the department level, various channels were recorded for the exchange of asset inventory and asset condition assessment information. Each channel was assessed against the following rating criteria; (i) the communication channel is not used; (ii) the communication channel is little used (once per six months); (iii) the communication channel is seldom used (once per month); (iv) the communication channel is occasionally used (once per week); and (v) the communication channel is the mainly used channel (once per day). Fig. 7 shows the general use of different communication channels at the municipality level.



	Face to Face Meeting	Telephone	Fax	Postal Mail	Disc (Floppy/CD/ Memory Stick)	E-mail	Instant Message	Audio Conferencing	Video Conferencing	Template based Exchange	Web Page Exchange	Server Based Exchange	Privately Dedicated Networks	Computer to Computer Automated
Unable to Rate	0	0	0	0	0	0	1	0	0	2	1	1	2	2
Not Used	0	0	1	0	0	0	7	2	5	8	1	1	7	6
Little Used	0	0	8	5	5	0	3	5	4	2	5	2	0	0
Seldom Used	0	0	2	4	2	0	1	3	3	0	0	3	0	0
Occasionally Used	1	2	1	2	5	0	0	2	0	0	3	2	0	4
Mainly Used	11	10	0	1	0	12	0	0	0	0	2	3	3	0

FIG. 7: Communication channel use at municipality level

Results indicate that face-to-face meetings, telephone, and e-mail were the main communication channels. Other than these main types of communications, all of the other types of channels received some use. For example, some municipalities report the use of the webpage-based exchange of information since they have well-developed web sites with extensive information and, in some cases, users can explore and exchange information through submitting query, incident reporting, and approval applications. Similarly, some use of privately dedicated networks and server-based exchange of information was reported since some municipalities have established file transfer protocol (FTP) servers through which they exchange large data files. The least-used are instant messaging and template-based exchange (essentially completing on-line structured data-field forms). Automated computer-to-computer communications were split between "not used" and "occasionally used"—thus they have clearly come into existence within municipal communications, though they are not yet commonplace. Overall, the results suggest that, despite the prominence of the three main communication channels, municipal workers will resort to a very wide variety of other communications channels—both computer-based and non-computer-based—as the situation demands.

Fig. 8 shows the communication channels used at the engineering/public works department level for the two specific communications of asset inventory and asset condition data reporting. Of the 14 communication channels, seven were used for the exchange of asset inventory and six for condition assessment data at the engineering services/public works department of the municipality. Again, a few communication channels are widely used (E-mail, face-to-face, server-based exchange, etc.), while a number of the communication channels saw no use. Analysis showed that there was sufficient data to confirm that these results showed statistical difference between the communication channel usage (an ANOVA two-factor with replication test showed that the value of "F" was greater than "F_{crit}" with p-value less than the alpha factor 0.050, indicating that there was a significant difference found between the use of fourteen different channels, the use of different channels for asset inventory and condition assessment processes, and city vs. district municipalities).

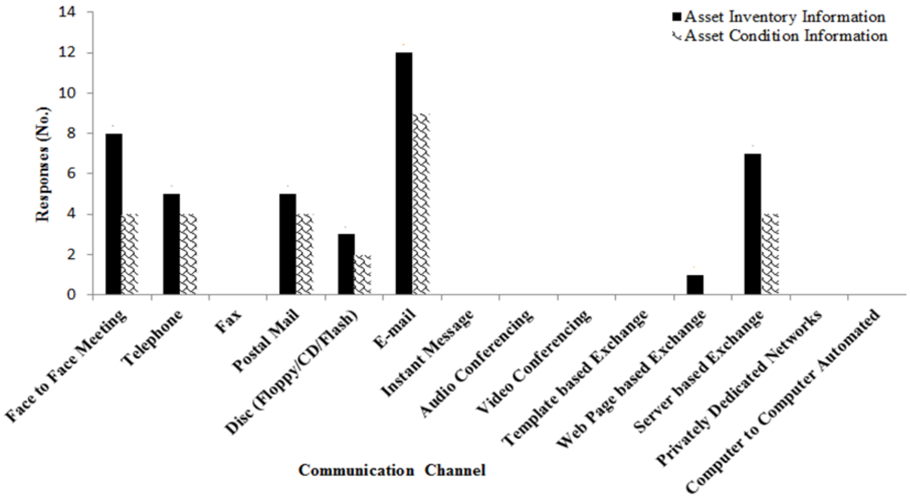


FIG. 8: Communication channel use for asset inventory and condition assessment data

Overall, the results shows that face-to-face meetings, telephone, postal mail, e-mail and server based exchange were commonly used channels by almost all city and district municipalities for the exchange of infrastructure information, indicating that the way information is currently exchanged is human-to-human, informal, unstructured, and is accomplished on ad hoc basis. Computer-to-computer based exchange of information is yet to play a significant role in these technical communications.

4.4 Methodology requirement analysis and transaction/communication identification

The last portion of the survey (Part C) explored the nature of the transactions that municipalities use to exchange infrastructure information between different organizations and different software applications. This work has been addressed elsewhere (Zeb et al., 2012) and is not the focus of this paper, but in brief, the results show that these transactions are typically carried out as needed using ad hoc methodologies. A move towards increased computer-to-computer data exchange requires methodologies to formalize these information transactions. In response to this need, we are developing a Transaction Formalism Protocol. Finally, the survey identified the following transactions as having a high potential to benefit from improved IT communications: asset inventory and condition assessment/tangible capital asset reporting, 10-year plan project reporting, asset replacement program review, pavement condition data reporting, request for proposal, submission of desired as-built information related to a given project, and request for services.

5. CONCLUSIONS

This survey has been conducted to benchmark the range of information system that the municipalities use to perform diversified work processes, benchmark communication channels to provide an insight on how municipal organization exchange infrastructure asset information; and to identify communications in the domain of infrastructure management that have the greatest potential for IT improvement. To achieve these objectives, a combination of web-based and face-to-face interview survey approach was used.

It was found that municipalities used a number of software applications to carry out different work process that were grouped into five categories; planning and scheduling, design, finance and accounting, management, and monitoring processes. A range of software was identified against each process category. Most of the municipalities were using updated version of the applications. Sixteen software applications were identified to accomplish six sub-processes of Asset Maintenance Management Planning Work Function. The two most commonly used software were Excel and dTIMS. Furthermore, interoperability of these applications at the data level was more 'between municipalities' in comparison to 'within municipalities', where it was vice-versa at the information level.

Similarly, communication channels were benchmarked at the municipality and department levels. It was found that face-to-face meetings, telephone, postal mail, e-mail and server based exchange were widely used modes of communication in municipal infrastructure management, emphasizing that current practices of information exchange are human-to-human, informal, and unstructured, and are accomplished on ad hoc basis. To improve current practices of information exchange, other modes of communication (e.g., template based or computer-to-computer automated) could be explored to achieve communication efficiency in terms of time, and effectiveness in terms of quality (right information to the right person at the right time), and cost.

As introduced at the beginning of this paper, the survey was conducted as part of a larger research effort to improve computer-to-computer information exchange between infrastructure organizations. The results show that, while municipalities do not commonly use this form of communication at present, they do routinely use the types of computer applications for a range of infrastructure management functions that provide the necessary environment for more advanced and efficient communications to take place.

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