# Methodology for Selecting Features of Mobile Technology for Municipal Inspections

Goggin, A.; Rankin, J.; Kondratova, Irina



**Publisher's version / Version de l'éditeur:**

*ASCE International Workshop on Computing in Civil Engineering [Proceedings], 2007*

National Research Council Canada
Conseil national de recherches Canada

Institute for Information Technology
Institut de technologie de l'information

NRC·CNRC

# *Methodology for Selecting Features of Mobile Technology for Municipal Inspections**

Goggin, A., Rankin, J. and Kondratova, I.
July 2007

* ASCE International Workshop on Computing in Civil Engineering, Pittsburgh, USA, July 2007, NRC 49301.



Canada

# Methodology for Selecting Features of Mobile Technology for Municipal Inspections

Ashley Goggin[1], Jeff Rankin[2], and Irina Kondratova[3]

[1]University of New Brunswick, Department of Civil Engineering, PO Box 4400, Fredericton, NB, Canada E3B 5A3, email: i8r19@unb.ca
[2]University of New Brunswick, Department of Civil Engineering, PO Box 4400, Fredericton, NB, Canada E3B 5A3, email: rankin@unb.ca
[3]National Research Council of Canada, Institute for Information Technology, 46 Dineen Drive, Fredericton, NB, Canada E3B 9W4, email: Irina.Kondratova@nrc.ca

## *Abstract*

Inspections are inherent in many steps throughout the management life cycle of municipal infrastructure. Mobile technology has the potential to improve information capture and management for inspections allowing for easier access, review, and increased detail. A plethora of possible technology solutions do exist but with few comprehensive techniques available to industry for adoption and implementation assessment. This research project's primary deliverable was the development of a method for selecting various technology features for a given inspection type with a medium-sized municipality's information technology division serving as the research client. Six different infrastructure inspections, encompassing extensive contextual aspects and user requirements, were used in the development of an analysis framework. The framework, comprised of elements that segregate inspections into generic steps and corresponding information and data requirements, placed an emphasis on the contextual aspects that may influence the applicability of technology. The results are intended as input for formal usability evaluations to validate functional requirements.

## *Introduction*

In recent years, the architectural – engineering – construction (AEC) industry has encountered two significant challenges: 1) effective information capture and 2) efficient information management. Inspections are a form of information management within the AEC industry that may be used for a variety of purposes ranging from asset management to life safety for any number of organizations or people. The efficient and reliable

management of information from inspections should thus be a significant concern for many organizations (Hwang 2006).

A potential solution to the aforementioned obstacles of efficient information management is the application of mobile technology. Through the combined effort of the National Research Council (NRC) of Canada and the University of New Brunswick (UNB) Civil Engineering Department, the focus of a research project was on the development of a framework for assigning various features and attributes of technology to inspections, based on their characteristics, using existing inspections provided by a client as a model. The potential application of multimodal interaction with mobile computing devices – the use of several input techniques such as stylus, speech, gesture, traditional and soft keyboard (Oviatt 2003) – was also investigated. Developing a better understanding of the contextual aspects that would influence the feasibility of certain applications of mobile technology and specific modes of interaction with this technology in the field was of key significance. Pascoe (2000) has identified four characteristics of mobile field usage requirements: dynamic user configuration, limited attention capacity, high speed interaction and context dependency. The relative importance of these factors depends on the type of the field work. In our study, in order to capture field work requirements for municipal inspectors a researcher, in addition to conducting interviews with managers and inspectors, was shadowing inspectors during the inspection process and recorded all details in the template forms. Using these template forms, the conditions of a particular inspection could be closely reconstructed in the laboratory in order to conduct usability testing for a chosen mobile device or evaluation of a data collection application on mobile device. Other important issues to be addressed related to usability aspects of mobile computing have been identified by Bürgy (2002), Kjeldskov (2003), and more recently Bowden (2005).

The City of Fredericton (CoF), New Brunswick, Canada, served as the main client of the research project and provided access to six separate inspections performed by City of Fredericton personnel. Using the set of inspections as a case study, the aspects of an inspection that influence the selection of different forms of technology was determined, along with several conclusions on how mobile applications of technology may potentially improve an inspection process. The primary goal of the CoF is the reduction of inspector dependency on the main office for resources and information; therefore, the inspections were evaluated based on this main objective. Recommendations were developed for each individual inspection as well as an overall recommendation for a base technology to be adapted by the municipality's Information Technology (IT) Division that would best fulfill the requirements of the majority of inspections.

The main objectives of this paper are to: 1) document the preliminary research performed and its relevance to the findings of the project, 2) discuss the research methodology used in the collection of information from the various inspections, 3) discuss the development of the analytical framework and its main components, 4) describe the significant findings and resulting implications of the research project for the client and for research purposes, 5) discuss the benefits of conducting a usability study

to validate the research findings through use of an inspection as a case study, and 6) propose potential research topics that may be of interest to future researchers.

### *Methodology / Approach*

Prior to the collection of data, it was necessary to define the range of potential information types and to identify the various functions of inspections. The overall approach consisted of several milestones to improve the collection and analysis process of the information.

**Classification of technologies.** The capabilities of current technologies were classified during the initial phase of the project. This task was accomplished using several resources available through electronic databases such as IEEE Xplore and the ACM digital library (IEEE 2006; ACM 2006). Computing technologies were separated into three main categories to better examine the diverse array of features that are available: 1) hardware, 2) software and the human-computer interaction aspects, and 3) additional attributes. Discussion and identification of the three categories was a valuable asset in the process of developing a framework for assigning attributes of technology based on specific inspection requirements. Fifteen key attributes of technology to be addressed during the analysis process included those listed in Table 1.

**Table 1: Key attributes of technology.**

| | | |
|---|---|---|
| 1. Mobility / portability | 6. Information for capture | 11. Compatibility with current |
| 2. Communication | 7. Information for access | 12. Adaptability |
| 3. Real time connection | 8. Data entry method | 13. Ruggedness |
| 4. Security | 9. Date display method | 14. Power requirements |
| 5. Relative size | 10. Usability | 15. Functionality |

**Perspectives of an inspection.** The three perspectives of an inspection were defined as: 1) process steps, 2) information requirements, and 3) contextual aspects permitting subsequent differentiation and identification of commonalities of a group of inspections.

Process steps provided a breakdown of nine distinct steps common among the majority of inspections to provide a comparative basis during analysis. The identified steps consider the various stages including pre-inspection, inspection, and the analysis and review process in order to delineate the flow of information and detect other matters of consequence beyond data capture.

The second perspective of information requirements detailed the type of information captured or accessed, which may range from textual to high resolution images. Several key issues affecting the selection of technology were identified within the third perspective, contextual aspects. For instance, environmental factors such as the weather would influence the feasibility of certain equipment and may require a water-proofing feature. It was this section in particular that proved to be valuable during the collection of information in the field from the inspectors and observation of the inspection's surroundings.

**Description of steps taken.** Information was collected through a series of interviews with the client's primary contact as well as with the Department Supervisor for each of the respective inspections. Further valuable data was gathered through a process of inspection shadowing to verify previously collected data and to gain further insight into all perspectives of a given inspection.

***Client Interview.*** A critical factor in the selection of mobile technology proved to be the set of requirements outlined by the research client, the CoF's IT Division. Although the contextual aspects of the current inspection process provide a significant amount of information as to what attributes of mobile technology would be appropriate in the field, the client may also have some specific issues or concerns that they would like addressed. Therefore, the viewpoint of the client often provided valuable feedback regarding the purpose and importance of the inspection and how the overall process may be improved.

The questions developed for the IT Division were designed to distinguish which features of technology were currently of interest versus the current IT infrastructure. In addition to being beneficial for the purpose of determining an overall technology solution for the CoF, the information collected from the interview was also an asset in the development of the framework for the research portion of the project. The information illustrated what aspects of data management are of particular interest to the client and what overall requirements they may have. Through documentation of the commonalities between various inspections, it was also shown that certain attributes of technology take precedence over others.

***Departmental Interviews.*** In addition to interviewing the main client, several interviews took place with each Department supervisor to determine their concerns and any particular requirements they may have. Each participant was asked a set of pre-defined questions to collect such information as: their personal level of knowledge and experience with mobile and multimodal technology, which inspection they would like to have studied, identification of specific contextual aspects of the chosen inspection such as its location, duration, and any potential hazards that may be present, training or certification that may be needed for the inspector, and any possible improvements that they would like to make to the inspection process. From the interviews it became evident that each participant had his/her own set of unique requirements and concerns to be addressed.

***Inspection Shadowing.*** Although interviews with the department supervisors provided valuable information regarding the purpose of the inspection, further investigation was needed to discern the actual inspection process that takes place in the field. To accomplish this through an observational study, each inspector was shadowed during an actual inspection and was then asked a series of questions to determine their opinions of the inspection process and how various forms of mobile, and possibly multimodal, technology may be beneficial.

The questions posed to the inspectors were designed to isolate specific environmental and contextual features of the inspection process that may impact the applicability of certain technology. For instance, one of the specific questions was "Are

your hands typically occupied or have material, such as concrete or mud, on them?" The inspector's response would determine whether or not hands-free data input would be necessary and if an easily stored device would be beneficial. The questions, together with field observations, also assisted in determining what tasks the inspector may be performing during the inspection. The shadowing process also provided a means of validating the participants' responses during the initial interviews.

***Functional requirements.*** Upon completion of the data collection process, each inspection underwent analysis using the template tables. Through use of the tables, the information for each of the inspections was narrowed down to specific requirements based on significant contextual aspects. The outcome of the analytical process was the selection of a form of mobile technology with the appropriate features and attributes to meet the defined requirements.

***Base Technology.*** To fulfill the expectations of the client, it was necessary to suggest a base technological solution that may be applied to a broad array of inspections. The final table within the developed framework was implemented by the researcher to compare and contrast each inspection to ascertain what features were of greatest importance versus those of little consequence.

### *Case Study*

Six distinct inspections were suggested by the client (Table 2) to ensure that the majority of potential contextual aspects, information types, and other critical issues were identified. From a research perspective, these distinct inspections allowed for the improved development of the analytical framework as a wide variety of factors were accounted for.

**Table 2: Inspections selected for analysis.**

| Department | Inspection | Description |
|---|---|---|
| Community Services | Playground | All playground equipment is inspected to ensure adherence to structural and safety standards. Distinction: Multiple locations and activities of the inspector. |
| Community Services | Skateboard park | All equipment is inspected to ensure adherence to safety and hygienic standards. Distinction: Frequency of occurrence. |
| Engineering and Public Works | Intersection | Inspection of a signalized intersection to meet the division's standards. Distinction: inspector safety and secure information storage. |
| Engineering and Public Works | Concrete curb | Inspection of a concrete pour for curb and gutter to maintain standards in the product and the contractor's performance. Distinction: multiple user constraints and need for improved access and storage of data. |
| Fire Department | Assembly | Places of assembly are inspected to ensure adherence to fire and safety codes. Distinction: reduction in duration and reliability of information. |
| Development Services | Building permit | Inspection of various stages of construction to ensure adherence to published standards such as the National Building Code of Canada. Distinction: access to extensive reference material in field. |

The primary goal of the client, the municipality's IT Division, is to enable an inspector to remain in the field for extended periods of time without having to depend on

the main office for information or other resources (i.e., breaking down the dependency on the office). Therefore, the requirements and expectations of the research client were focused on capturing both the diversity that exists between the inspections, as well as shared attributes and commonalities.

### *Analysis*

The analysis of the information collected from the interviews and shadowing of inspections was done using templates developed during a preliminary analysis. A description of each of the eight templates is shown below in Table 3.

**Table 3: Data collection templates.**

| Template | Description |
|---|---|
| A Client interviews | Compilation of client answers and general comments. |
| B Inspection shadowing | Description of the individual process steps, any identifiable contextual aspects, and the methodology for data capture and information type. |
| C Inspection validation | Comparison of Tables A & B for validation. Provides insight to the variance of individual opinions depending on their responsibilities (i.e. supervisory position versus the inspector). |
| 1 Description of individual process steps | Intended for each process step of an inspection to address information and resource requirements. Identifiable drawbacks are described with recommended solutions with an emphasis on the benefits of mobile technology. |
| 2a Participant specifications | The requirements of Table A & B categorized according to fifteen attributes of technology. |
| 2b Client specifications | Information gathered from the main client contact, the IT Division, categorized according to the same fifteen attributes of technology as in Table 2a. |
| 3 Technology requirements | The final set of recommendations for individual inspections with an emphasis on the features of technology to address contextual aspects. |
| 4 Chosen technology | Compilation of recommendations for all inspections with a summary of common features and requirements. A base technology is then chosen based on the individual concerns and the stipulations of the IT Division. |

Each template document shared a common section for general information, which included such data as the participant's name and department, the name of the inspection, the inspection's function, the type of location, and its frequency of occurrence. This was done to better manage and sort the multiple forms that were completed for each of the six inspections as provided by the client.

For example, based on the data collected for the concrete curb inspection, the most suitable form of mobile technology was determined to be a handheld device due to its durability, small size, and its ability to enter information with a stylus as the majority of data captured are predefined options rather than open-ended comments. The inspection, though, takes place outside which would suggest the need for a water proof feature and a glare proof display screen. As well, due to the excessive noise levels (often exceeding 100 decibels) speech input may not be possible at all times. A secondary option would be to use a rugged tablet computer.

Upon completion of the recommendations for the individual inspections a base technological solution for municipal inspections was proposed. By comparing separate

recommendations, determining the specific attributes of significance, and including the requirements of the client, a tablet computer was identified as a feasible option for the client to consider. The suggested features included a display screen that is both water and glare proof, be of durable material, with multimodal capabilities, having the option of a real time connection, be supportive of varying information types, and be equipped with security features such as user identification, passwords, and data encryption at the minimum.

To validate the assumptions and the resulting findings of this research it is recommended that a usability evaluation be performed in the laboratory and the field which could not be accomplished due to time constraints. Selection of the most appropriate inspection for a usability evaluation is of importance as it must depict a broad range of requirements and contextual aspects that would influence the applicability of mobile multimodal technology to achieve an adequate representation of all inspections while simultaneously ensuring that the evaluation design will not become overly complex or simple.

### *Conclusions*

The project's primary deliverable was the development of a method for selecting various features of technology for a given inspection. Based on field observations and interviews, it was found that there were several requirements common to all of the inspections analysed regardless of their function. This result shows that it may be possible for an organization, such as the CoF, to select one technological solution for multiple inspections, and then to apply special features as they may be needed to suit the individual requirements of particular inspections. In this particular case the CoF results such as mobility and a real time connection were found to be the most influential attributes for the given inspections.

Analysis was performed based on the information collected from the various interviews with the participants and from the process of shadowing the inspections. Both methods served as valuable tools for acquiring the necessary information. Although the two approaches complemented each other and served as a means of validating the information, the vast majority of the data was collected from the shadowing process in the field. While in the field, a broad range of contextual aspects for each inspection were identified through observing the inspector performing the actual tasks. This provided a better understanding how a mobile device may potentially be applied for use in the field and how it may improve information capture and management.

Several of the data collection and analysis templates that were developed in this project underwent modifications due to emerging requirements throughout the duration of the project. Although the templates were able to serve the purpose of the project it is expected that as other inspections are analysed the templates will need to be further improved to better capture the broad range of possible contextual aspects and requirements of participants that there may be.

The primary goal of the templates was to analyse a given inspection process to ascertain how its individual characteristics would influence the applicability of certain forms of technology independent of a specific technology. The results obtained provide all the information necessary in order to develop usability tests for validation.

***Acknowledgment***

The researchers acknowledge the contributions provided by the employees at the City of Fredericton. This research project was supported by the Natural Science and Engineering Research Council of Canada and the New Brunswick Innovation Foundation.

***References***

ACM (Association for Computing Machinery) (2006). ACM Digital Library Portal. Accessed May 2006, last updated 2006. Available from the Internet at: http://portal.acm.org/dl.cfm

Bowden, S., Dorr, A., Thorpe, A., Anumba, C. J., and Gooding, P., (2005). "Making the Case for Mobile IT in Construction", *Proceedings of the ASCE International Conference on Computing in Civil Engineering*, Cancun, Mexico. July 11-15.

Bürgy, C., and Garrett, J.H., Jr., (2002). "Situation-aware Interface Design: An Interaction Constraints Model for Finding the Right Interaction for Mobile and Wearable Computer Systems," *Proceedings of ISARC2002*, Washington, D.C., September 23-25.

Hwang, S.; Trupp, T.; Liu, L. (2003). "Needs and Trends of IT-based Construction Field Data Collection", *4th Joint International Symposium on Information Technology in Civil Engineering*, Nashville, Tennessee, November 15–16.

IEEE (2006). IEEE Xplore release 2.1. Accessed May 2006, last updated 2006. Available from the Internet at: http://ieeexplore.ieee.org/Xplore/dynhome.jsp

Kjeldskov, J., and Graham, C., (2003). "A Review of Mobile HCI Research Methods" *Proceedings of the 5th International Symposium on Mobile Human-Computer Interaction (MobileHCI'03)*, Udine, Italy, Sept. 8–11.

Oviatt, S. (2003). "User-Centered Modeling and Evaluation of Multimodal Interfaces", *Proceedings of the IEEE*, 91(9), 1457-1468.

Pascoe, J., Ryan, N. and Morse, D. (2000). "Using While Moving: HCI Issues in Fieldwork Environments", *in ACM Transactions in Computing-Human Interactions*, 7(3) 417-437.