

Real-Time Capture of Equipment Installation Information (2019-09-04)

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Author's Note: This paper is being released in partial draft form to document the current work of simulating the life-cycle capture of COBie data on the East Dormitory Project to be published under Creative Commons license by Prairie Sky Consulting. In this version of the paper, the work required complete the research to the standard required of academic publication is incomplete. As additional portions of the work outlined in this paper are accomplished, the paper will be updated. Beyond the benefits realized by the research itself, the potential for conducting crowd-sourcing construction management research will be evaluated as an alternative research methodology to structured interviews and general surveys.

Background

The Construction Operations Building information exchange (COBie) standard describes how to organize, capture, and deliver an electronic copy of the equipment operations, maintenance, and management typically delivered long after an owner has moved into a new or newly renovated building. COBie identifies two major deliverables one during the design of a project and one at the end of construction. Today, many design disciplines use Building Information Modeling (BIM) software that has been demonstrated to deliver accurate COBie data (East 2015, 2017). Once COBie data is delivered to the owner, most major software vendors in this domain have demonstrated their ability to import COBie data saving thousands of man-hours that would have been spent recapturing and manually entering as-built equipment and maintenance information (bSa 2014).

Capturing information during construction remains, however, an open question due to the dynamic nature of construction contracting and administration process. The goal of capturing COBie data during the construction process, regardless of the quality of information provided during design, was the primary objective of the original COBie specification (East 2007). In fact, the original COBie specification had a data schema that mirrored each type of construction administration form containing a partial set of COBie data. Unfortunately, during the process of data normalization and standardization the emphasis on "how" COBie data was to be captured during construction was deemphasized.

To demonstrate that common construction administration processes could be adapted to both the traditional Design-Bid-Build and the Design-Build construction procurements, the term Lean Handover™ was coined (East 2019). In that book, the original intent of the COBie standard was reemphasized as capturing each bit of handover data as it appears during the construction process. The result is that at the end of a project there would not be a need to conduct post-construction job surveys or even to produce operations and maintenance manuals. All the needed information would have been be already captured electronically as a by-product of the construction administration process. The resulting information could, depending on the owner's contractually stated requirement, could then be "printed" in any electronic or document-based format needed.

As part of an on-going effort to demonstrate the practical use of commercial and open source software to deliver COBie data, a volunteer team of designers, builders, consultants, and software engineers have been creating a set of life-cycle data for one simulated building. The building is called the “East Dormitory.” It is being virtually constructed on a fictional site in Champaign, Illinois. This two-story building contains living and dining spaces on the first floor and a set of bedrooms with adjoining full bathrooms on the second floor, Figure 1.

Since the contractual context for the project had to be set as part of the simulation the traditional Design-Bid-Build model of procurement was adopted. During the design stage of the project two teams were engaged one for the concept design and another team to complete a simulated set of construction contract document drawings. Simulated construction data such as product selection forms and jobsite photographs have also begun to be released under Creative Commons licensing by this team (PSC 2019).



Figure 1 East Dormitory Section Rendering

Introduction

One of the key steps in the construction of every building, and therefore the collection of COBie-relevant information, is equipment installation. Today, general information about equipment installation is collected manually on daily reports. Information about specific information may also be documented using a variety of different company-specific management methods. The most rigorous of these are color-coded hand-written tags placed on the equipment by the workers themselves. These tags signify the status of installed equipment starting with placement, piping connection, electrical connection, startup, and testing.

Either by contract or convention there is a common understanding that having the installed model number, the serial number, installation date, and energization date are important pieces of information to capture. As a result, this information is also required to be delivered using COBie. Traditionally the subcontractor’s mechanics installing equipment do not participate in COBie data collection. That job is left to the prime contractor, or a separate subcontractor, who must literally crawl through the building’s ceilings and mechanical rooms after the project has been completed. Often getting accurate information is not possible without tearing insulation, breaking ceiling tiles, or using hand-held mirrors to see occluded nameplate data.

Hypothesis

The of this research is that the overhead cost spent by prime contractors, or their subcontractors, to collect as-built equipment information can be reduced or even eliminated by requiring equipment installers to capture as-built equipment data when the equipment is installed, energized, and tested. In this paper we consider the data that can be gathered by equipment installers at equipment installation.

Assumptions

This paper begins with the assumption that equipment installers have either personal or company issued cell phones that they carry with them during the day. Based on that assumption we posit that a phone-based application can allow the installer to document their work. In the case of equipment named on construction drawing schedules, that information would include equipment nameplate data. In the case of products identified by type or mark on construction drawings, that information would simply include the data of installation. As the information is captured it can then be aggregated and used to provide COBie data deliverables.

The second assumption of this paper is that spotty or inadequate internet connection is not uncommon in the construction industry. In remote locations, when an internet connection is provided to the project team through the contractor there will typically be insufficient bandwidth for field workers to effectively use the network. In areas where there is widespread coverage, such as city centers, data and wi-fi services often cannot reach building interiors surrounded by steel and concrete.

The final assumption of this paper is that traditionally problem-solving, innovative spirit of workers in the construction industry can be harnessed from within a company. This assumption flies in the face of top-down innovation approaches imposed by corporate offices. The application of all-in-one software, while a dream of many in the construction industry since the 1980's, often fails to live up to expectations. There is typically a wide disconnect between the expectation of use of enterprise construction systems and the actual experience of those in the field.

Approach

This work begins with evaluating the work environment of equipment installers to determine the types of devices that may be best suited to use for on-site data collection. Based on that analysis, an application development platform was selected and an application created. This application was provided for the community of contractors, subcontractors, and research to review and consider as part of the release construction phase COBie data on the East Dormitory project.

To evaluate the truth of the hypothesis an additional set of information is required beyond that provided in this paper. There are three basic types of information required.

The first type of information considers the validity of the assumptions posed above. Should these assumptions not hold true then the costs of any approach similar to that proposed in this paper would need to be adjusted.

The information pertain to the differences between current practice and the proposed practice are also required. For each type of practice, the expected cost of data collection and collation into COBie

format are required. While these values will be an estimate, those with direct experience collecting such information on similar buildings will be able to provide a reliable estimate.

Finally, an estimate of how those costs would increase on projects of different size and complexity should be conducted. The results of this estimate should be considered on a more qualitative basis due to the variety of different types of projects that may be encountered.

The method used to collect such information in many academic settings has traditionally been the survey. This paper will not use a survey methodology since the survey is unlikely to reach the intended audience. While direct interviews with experienced practitioners may be critiqued for being based on the experience of one, or a few, individuals. Any results obtained will be grounded in many years of hands-on experience.

Selecting the Open Data Kit Platform

The Open Data Kit (ODK) project was originally created to assist those using low-cost Android phones to collect medical compliance reports in remote locations with no cell-tower reception or network connections. The work was developed to create a modular data collection infrastructure allowing local adaptation instead of mandating monolithic enterprise data systems on field workers (Anokwa 2009). All code necessary to create, publish, and collect form data is for anyone to use for any purpose under a Creative Commons License.

Given the ability of the free ODK platform to capture data in the field and collect the information when networks are available and to support flexible and ad-hoc end-user data capture by subcontractors ODK was selected to for this demonstration.

From the software development point of view ODK was written in the Python programming language using the Django framework. The elements of the most common ODK platform include the “ODK Collect” application used to display forms to the user, the “ODK Aggregate” server that collates form data from multiple users, form designers, and desktop tools (ODK 2017).

To use ODK Collect, form templates are prepared and stored on the ODK Aggregate server. Upon successful login to the server, the form or forms may be downloaded in the ODK Collect application. When form data is collected, it will be automatically sent to the server whenever network coverage can be established.

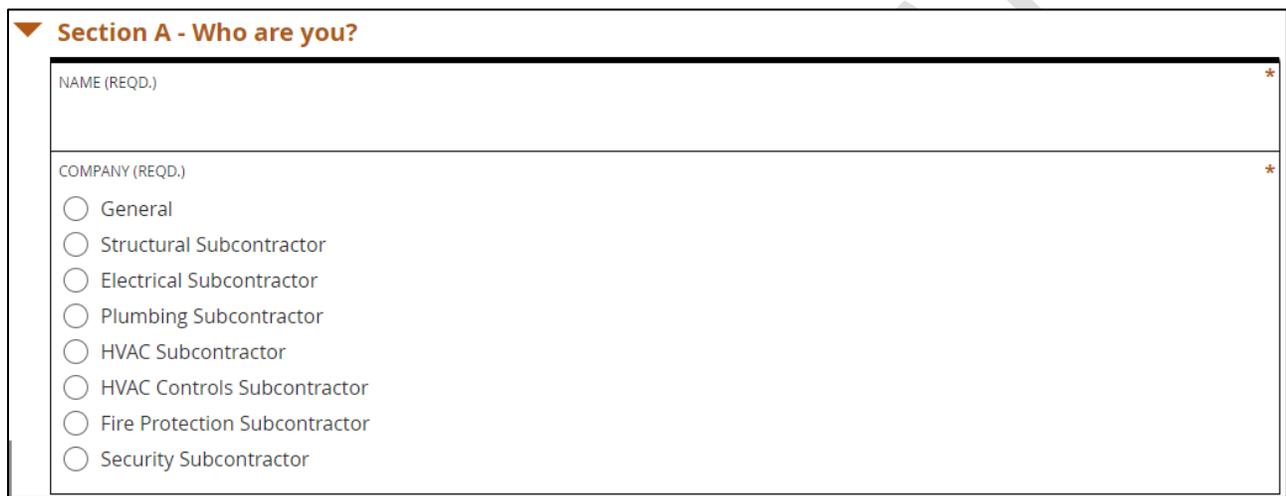
Form creation is accomplished in a spreadsheet using a standard form authoring language called XLSForm (XLSForm 2019). Each form is created using three spreadsheet tabs: Survey, Choices, and Settings. The Survey tab contains the groups of questions that comprise the survey. Question types determine the user interface provided. For questions containing pick lists, the second, Choices, tab provides the list of choices. The final, Settings, tab optionally provides information about the use of the form.

While it is possible for the ODK Aggregate server to be inexpensively hosted on a company’s external webserver running Tomcat, it may also be hosted on any number of commercial service providers such as Amazon Web Services. For the complete range of options, readers should refer to the ODK Aggregate documentation (ODK 2017).

Creating and Hosting the Equipment Installation Form

With the federated set of design-stage data for the East Dormitory project already being published in COBie format (PSC 2019), the creation of the associated equipment installation form was simply accomplished. To use the form the equipment installer completes a three-part form. The first section of the form asks, “Who are you?”. The second section asks, “Where are you?”. The third section asks, “What are you installing?” To provide create a generic form for the initial testing, one form was created for the entire East Dormitory project (PSC 2019).

“Section A” of the form asks the user to provide their name and pick name of their company. While a generic list of companies provided in the example form, an actual project would have the list of contractors and subcontractors for the project. Figure 2 shows the web-browser view of the questions in Section A.



Section A - Who are you?

NAME (REQD.) *

COMPANY (REQD.) *

- General
- Structural Subcontractor
- Electrical Subcontractor
- Plumbing Subcontractor
- HVAC Subcontractor
- HVAC Controls Subcontractor
- Fire Protection Subcontractor
- Security Subcontractor

Figure 2 Installation Form (Section A)

Section B of the form asks the user to select from the list of the COBie.Floor.Name fields. In the case of the East Dormitory Project there were three floors. Once floor has been selected from the set of radio buttons, the list of COBie.Space.Name values on that floor appear in the next question. In Figure 3, the selection of “Level 1” was made. Before moving to identify information about installed equipment or products, the room number and name must also be selected.

“Section C” form asks the user to select a piece of equipment or named product installed in that room. Once selected, the user can enter any of the following information that is appropriate for the item: Serial Number, Installation Date, and Energization Date. Photographs of the equipment’s nameplate and general installation setting may be collected. GPS data provided by the phone may also be collected. Importantly, if the equipment location has been changed from that identified by the original COBie data, then the form allows the user to select the room in which the equipment is actually installed.

▼ **Section B - Where are you?**

FLOOR (REQD.) *

Level 1

Level 2

Level 3 Roof LP

SPACE (REQD.) *

001. Exercise Terrace

002. Terrace

101. Exercise Room

102. Toilet

103. Toilet

104. Storage

105. Mechanical Room

106. Bath

107. Closet

108. Break Room

109. Elec/Tel

110. Laundry

111. Storage

112. Kitchen

113. Food Storage

114. Pantry

115. Outdoor Storage

116. Stair 2

117. Hall

118. Recreation/Dining Room

119. Bar

120. Storage

121. Living Room

122. Closet

123. Entry

124. Closet

125. Stair 1

128. External Space Level 1

Figure 3 Equipment Installation Form (Part B)

Figure 4 shows the result of having selected “103. Toilet” in the previous part of the form. At the top of the form is a set of check boxes allowing the selection of one or more of the COBie-based equipment or products listed in this room. These values are directly created from the COBie.Component.Name rows found in the COBie.Component.Space, selected in Part B of the form. The form is set up to allow basic information about multiple Components to be entered at once. This is appropriate for the lighting fixtures, doors, and other products that do not have serial numbers. Users may select one or more product and provide information as noted in the form below. This information includes photographs and GPS location.

Section C - What did you install?

COMPONENT (OPT.) *

Ceiling-Exhaust-SP-A10

CeilingLight-RoundEmergencyA_39

CeilingOccupancySensor_6

DR:T1B_D103_216479

Floor Drain - Round-1

Lavatory-Wall Mounted-2

Smoke Alarm-32

Sprinkler - Dry - Pendant - Hosted-51

TA:T40_552090

TA:T40_552193

Toilet-3

OTHER (OPT.)

SERIAL NUMBER (OPT.)

BAR CODE (OPT.)

INSTALLED ON (OPT.)

yyyy-mm-dd ↻

NAME PLATE PHOTO (OPT.)

Click here to upload file. (< 5MB) ↻

GENERAL PHOTO (OPT.)

Click here to upload file. (< 5MB) ↻

GPS LOCATION (OPT.)

latitude (x.y °) search for place or address 🔍

longitude (x.y °) 📍



Figure 4 Equipment Installation Form (Part C)

Following the creation of the Equipment Installation Form, a commercial ODK platform provider, that allows free accounts was selected. The domain name for this service provider is ona.io.

Installing the Equipment Installation Form

At this time anyone may download and use this form as noted below.

1. On your Android phone, go to the Google app store on your Android phone. Search for “ODK Collect” Application. Download and enable app permissions, as prompted.

2. In your phone's or computer's internet browser, Go to the www.ona.io website and create a free account.
3. As part of that account creation process, follow safe password practices. Add your user account and password to your password manager program so that you can reference it in the future.
4. For the purpose of this exercise, indicate that you are not collecting EU citizen data. In fact, you will only be submitting fictional data to the server.
5. Logout of ona.io, close your browser. Return to ona.io and login again to make sure you have correctly documented your account credentials. Then, logout again to verify your account is working correctly.
6. Send your ODK username to bill.east@prairieskyconsulting.com with the subject heading "Request ODK Access" and I will provide you access to the form. Once I have confirmed your ODK username, you will be allowed to download the form.
7. Open the ODK Collect application on your phone.
8. In ODK Collect's opening screen press the Menu button. Select the General Settings option. Select the Server sub-option, Figure 5.

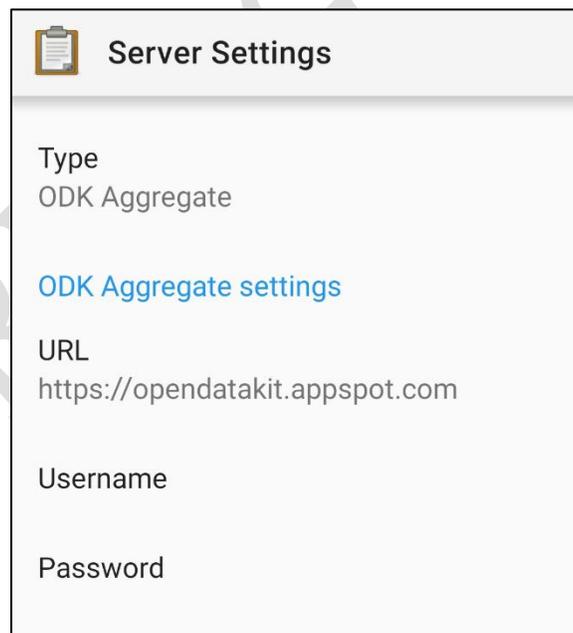


Figure 5 ODK Collect - Server Settings

- a. Do not change the Type value.
- b. Edit the URL to be: "https://odk.ona.io".

- c. Enter your ona.io username and password.
9. Return to the “Main Menu”
10. Click the “Get Blank Form” button.
11. The blank form “DormEquipment01” should now be available for you to download, Figure 6.

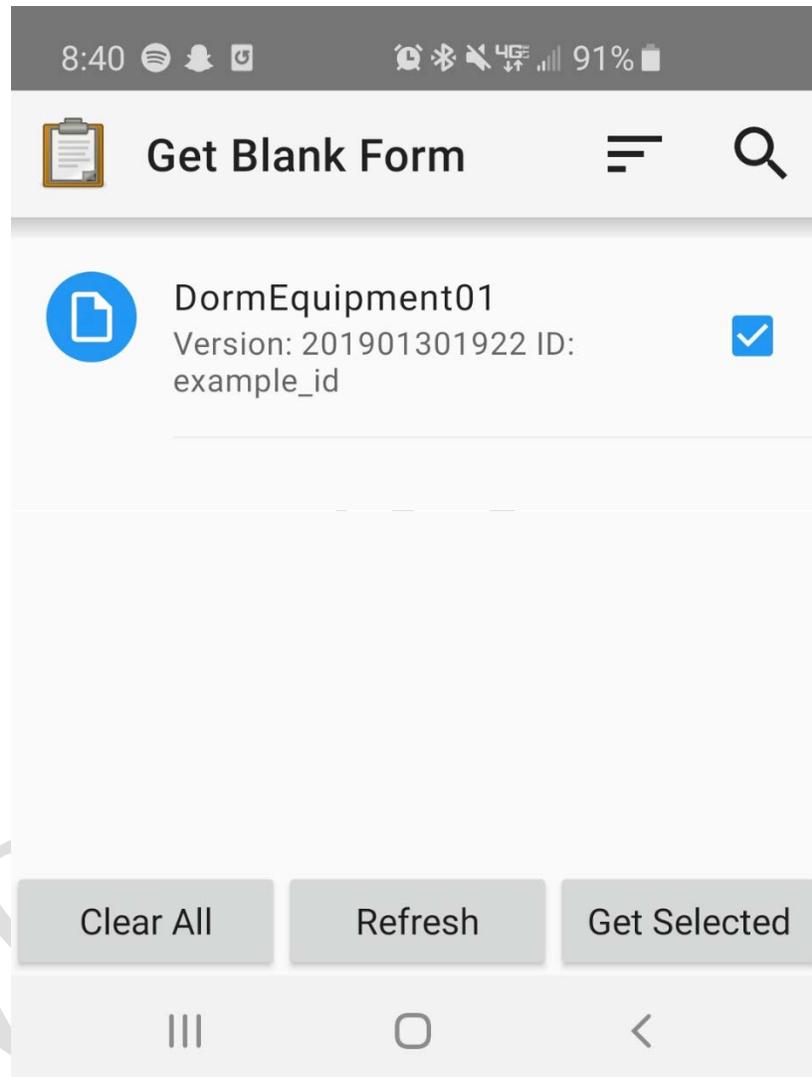


Figure 6 ODK Collect - Get Blank Form

12. Select the form and click “Get Selected” to download the form. Return to the main menu and select “Fill Blank Form”. Select the DormEquipment01 form.
13. The opening screen of the form tells you the name of the project, Figure 7.

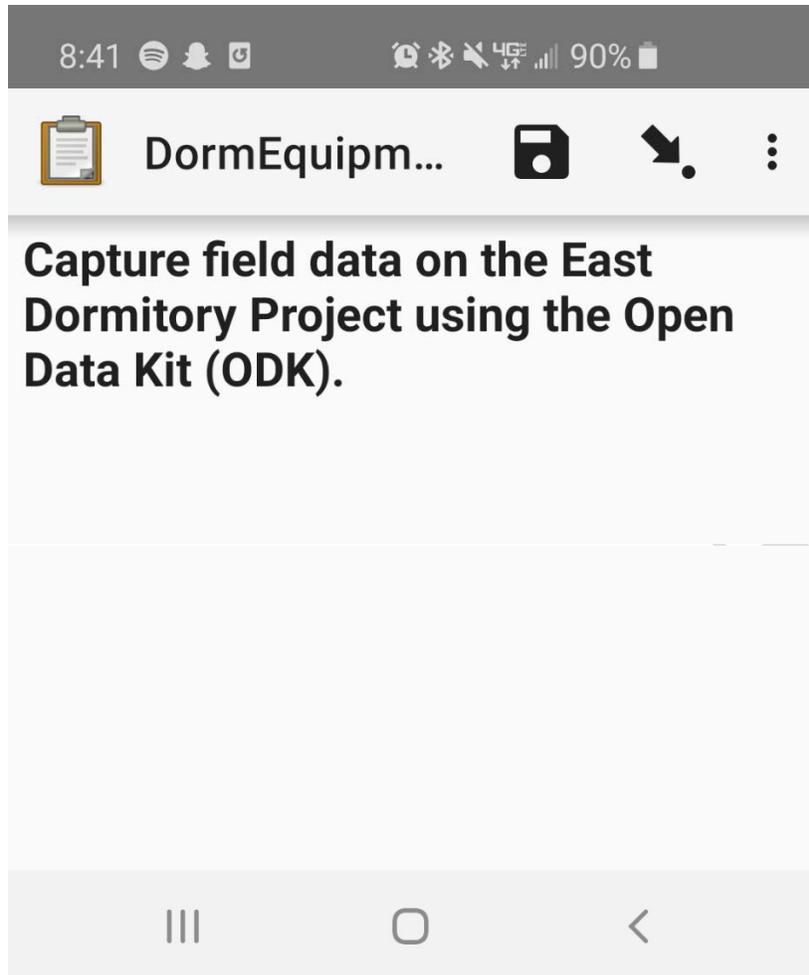


Figure 7 ODK Collect - Form Welcome Page

14. To ensure that the free ona.io account being used does not exceed the “free” limit that has been set, I ask you to also do the following before using the form. Send an email to bill.east@prairieskyconsulting.com with the subject heading “ODK Collect Form Download Successful.” At this time, I will need to change your permissions to view-only. You will be unable to re-download the form but will be able to find it under the “Fill Blank Form” option.
15. After you have received a message back from me to proceed, you may begin to try the form. Open the form. To move forward and back between form pages, you can swipe left or right. To see the overall organization of the form, click the arrow icon in the form’s menu bar.
16. Try out the form a few times on different floors and different rooms. Instead of posting your form results to the server, save your results to your phone.
17. Consider how similar apps could be customized for different trades that reflect only the list of rooms and equipment in which they are installing equipment. Consider the ability to

create simplified lists that only display the expected work areas currently being considered. Please write down, in a draft email any thoughts you have in this area.

18. Now consider the traditional process of field data collection. Please write down, in the draft email your estimate of the number of times information similar to that provided in the app is typically collected during a construction project. Please consider not only the installer and foreman, but also the QA/QC staff, contract administration staff, and handover staff.
19. Finally, in the draft email, please provide a rough numeric estimate, using any terms or factors you think might be appropriate of the difference in cost of collecting and sharing the equipment installation once with that of collecting and recollecting the information as noted above. Please send this email to bill.east@prairieskyconsulting.com with the subject line "ODK Collect Estimate".

Results

Author's Note: This section provides an initial set of the Results of this research as of the date shown in the footer of this page. As the work proceeds, this section will be updated.

As of the date noted in the footer no results have been obtained.

Conclusions

Author's Note: This section provides an initial set of some of the currently expected Conclusions of this research as of the date shown in the footer of this page. outcome of the data collected during this research change, then this section will be updated.

While this example demonstrated the most basic form of equipment installation application, additional customization, particularly on large projects, will be important. For many projects separate forms will need to be created for each subcontractor or type of equipment. It may also be important to provide sub-forms within those categories for different project work areas or phases. The increased cost of creating these sub-forms, ensuring the correct form is available and used, and that data can be tested then merged will be important as this approach scales to major projects.

The sample form created for this project can be significantly streamlined by automatically collecting some information directly from the user's phone. As phones are no longer shared devices, the phone number from which the data is provided can be used as a proxy to identify each equipment installer. Once users adapt to providing real-time information, questions about the date

of installation, even when defaulting to the current date, can be eliminated from the app. While it is beyond the scope of the ODK platform, it is also possible to collect accurate internal building using either GPS or inertial navigation (Taneja 2012).

Recommendations

Author's Note: This section provides an initial set of some of the currently expected Recommendations of this research as of the date shown in the footer of this page. Should the outcome of the data collected during this research change, then this section will be updated.

Collecting COBie data by equipment installers provides a very near real-time window on the status of progress related to equipment installation. Having this information should be directly useful to the construction contractor in ways that we currently cannot anticipate since project updates are typically only conducted monthly for purposes of progress payments.

The use of cell phones has been demonstrated to be a major distraction for drivers. Use of electronics during driving has been shown to impair driving as much as drunk driving. When requiring the use of cell phones by equipment installers, it would be necessary to also study the safety risks on the construction site. Mitigating these risks by providing locked-down phones and mandatory safety training is a critical step in implementing any such equipment installation application.

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