<table>
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<tr>
<th>Proposal number:</th>
<th>2018-08</th>
</tr>
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<tr>
<td>Proposal title:</td>
<td>Comparing Different Delivery Methods of Contextual Work Instructions for Construction Laborers</td>
</tr>
<tr>
<td>Principal investigator(s) and department(s):</td>
<td>Prof. Martin Fischer</td>
</tr>
<tr>
<td>Research staff:</td>
<td>Rui Liu</td>
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<tr>
<td>Total funds requested:</td>
<td>$ 51,978</td>
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<td>Project URL for continuation proposals</td>
<td><a href="https://cife.stanford.edu/Seed2016_WorkInstructions">https://cife.stanford.edu/Seed2016_WorkInstructions</a></td>
</tr>
<tr>
<td>Project objectives addressed by proposal</td>
<td>Operable</td>
</tr>
<tr>
<td>Expected time horizon</td>
<td>&lt; 2 years</td>
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<tr>
<td>Type of innovation</td>
<td>Incremental</td>
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**Abstract (up to 150 words)**

**The problem:** Current methods of delivering work instructions to construction laborers do not quickly respond to changes of contexts and cannot convey contextual information in a timely manner.

**The proposed solution:** This research aims to investigate and compare different delivery methods of work instructions for construction laborers. I will compare delivery methods with two criteria: dynamic and timely. A delivery method is preferable if it adequately captures dynamically changing contexts and conveys contextual information in a just-in-time manner.

**The proposed research approach:** (1) Formulate delivery methods for work instructions such as via paper, smart phones, tablets, and augmented reality glasses. (2) This requires engineering solutions such as developing prototypes for each selected delivery method. (3) Validate each delivery method with an industry collaborator through a case study method, in which I will make both a qualitative and quantitative analysis of the delivery method.
1 Research Problem

This Seed Proposal aims to address the problem that current methods of delivering work instructions to construction laborers do not quickly respond to changes of contexts and cannot convey contextual information in a timely manner. Contexts, from construction laborers’ perspective, include location, task at hand, design, equipment, tools, and weather, and all of them are subject to changes. Consider a scenario when a laborer tries to install ceiling while the height of ceiling is unclear, and then how to quickly pass the right information to the laborer to finish the installation? It is such a common but important question in the construction world.

From the value stream perspective, construction laborers conduct the final value-adding activities at the work face, and therefore how they perform their tasks would considerably impact the project performance. Whereas research on work instructions has been very limited, Mourgues and Fischer (2008), among the few researchers who realized the importance of work instructions, put forward a method to generate field instructions for laborers to provide necessary information for performing tasks. However, their method was constrained by technologies at that time, and as a result, the delivery of work instructions could be problematic due to the lack of instantaneity and no inclusion of sufficient contextual information (e.g., information about how to deal with unpredicted design changes).

2 Theoretical and Practical Points of Departure

2.1 Previous Seed Research

This Seed Proposal is based upon a 2016 Awarded Seed Research titled as “Creating More Value-adding Work Instructions for Construction Laborers”. The previous Seed Research put forward extended criteria, which define high-quality work instructions as being more value-adding, informed of changes, attentive to construction laborers’ concerns, and just-in-time. Following these extended criteria, the high-quality work instructions could provide laborers with sufficient contextual information that is closely related to their tasks at the right time. Thereafter, the previous Seed Research provides a template, which aligns with the extended criteria, to enable construction practitioners quickly generate high-quality work instructions. The template consists of different information sections to cover different aspects of contextual information, as shown in Figure 1.

To validate the work instruction template, the research staff of the previous Seed Research collaborated with one CIFE member, Accu-Crete, to conduct a field study for one year. One test project was a ten-level residential building. The footprint of this project is 13,508 square feet, and the gross area is 149,220 square feet. Accu-Crete was the concrete sub-contractor for this project. Figure 1 shows an example of work instruction that the research staff developed particularly for this project. As shown, the work instruction has different information sections including: “Task Description”, “Floor Plan”, “Equipment and Tools”, “Part-related Information”, “Dependency Information”, “Instructions on the Installation Process”, “Laborers’ Concerns and Protection Measures”, and “Adjustments to Variations”. Those information sections are intended to ensure that construction laborers receive sufficient contextual information. In addition, the work instructions are designed to be interactive with laborers in that laborers can indicate if they think the instructions are helpful or not by checking the green or red box, respectively. Laborers can also

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put feedback in the “Adjustment to Variations” section to provide information on the changes of contexts on the jobsite.

Throughout the field study, the research staff conducted both a qualitative and quantitative analysis. On the one hand, the author was able to collect positive opinions on the customized high-quality work instructions. On the other hand, however, the research staff had difficulty collecting quantitative metrics and asking laborers to implement the work instructions as their daily routine. Main reasons accounting for this dilemma are listed below.

- Construction laborers thought it unnecessary to implement the work instructions because it can cause extra work for them;
- Some construction laborers cannot fully understand the written work instructions as they have varied levels of education; and most importantly
- The work instructions were delivered in a way that was not convenient for construction laborers to implement.

![Figure 1. An Example of Work Instructions](image)

Based on this preliminary case studies, the research staff realized the importance of applying effective delivery methods to convey contextual work instructions. Hence, the research staff will further formulate and compare different delivery methods.

### 2.2 Research on Communication Medium

An important aspect of work instruction delivery method is the medium through which the information is conveyed. Murray et al. (2007) categorized the medium into two types: one-way medium (e.g., letters, drawings, emails or faxes) only allows unidirectional information flow; two-way medium (meetings, telephone calls, conferences or software applications) allows...
multidirectional information flows\textsuperscript{2}. Compared to two-way mediums, one-way mediums hinder feedback. Therefore, in order to deliver work instructions to construction laborers, two-way mediums are preferable as they help collect feedback on the changes of contexts at the job site.

Although the above-mentioned communication mediums are mainly traditional ones, information technologies will profoundly change the way information is exchanged in the construction industry. In fact, since the first day when building information models was implemented, information technologies (e.g., computers, software, networks, and smart phones) have already been applied to assist communications in the construction industry. Nowadays, it is common to see laborers use smart phones and tablets to exchange information, which indicates an increase in exchanging information using electronic forms. In addition, one recent trend of BIM (Building Information Modeling) research is applying Virtual Reality (VR) or Augmented Reality (AR) technologies to facilitate information exchange with better visual representations and enhanced intelligence\textsuperscript{3}.

2. 3 Research on Evaluation Criteria of Work Instructions Delivery

As a comprehensive study indicates, work instructions should be clear, concise, complete, error-free, meaningful, relevant, accurate, and timely for the laborers. More specifically for the construction industry, work instructions should be written, complete, self-contained, specific, formal, dynamic, explicit, concise and illustrative. Those criteria measure different dimensions of work instructions (i.e., content, format and delivery).

- **Content**: complete, error-free, meaningful, relevant, accurate, and self-contained;
- **Format**: clear, concise, written, formal, explicit, and illustrative; and
- **Delivery**: timely and dynamic.

As this Seed Proposal is more focused on the delivery of work instructions, criteria falling into this dimension will be applied to compare different delivery methods. ‘Timely’ means that work instructions should be delivered prior to the time laborers start their tasks. Work instructions being dynamic means that the delivery method should dynamically capture changes of contexts.

3 Research Methods and Work Plan

This research intends to compare different delivery methods of work instructions for construction laborers. The research will be conducted in the following ways: (1) Formulate different delivery methods for work instructions; (2) Develop engineering solutions such as developing prototypes for each delivery method; and (3) Validate each delivery method with industry collaborators.

3.1 Formulate Delivery Methods for Work Instructions

A delivery method should include four main constituents (or sub-processes): communication medium, preparing instructions, using instructions and updating instructions. The medium through which instructions are conveyed will have impacts on the sub-processes. Communication medium are measured in two dimensions: accessibility and portability. Table 1 lists four communication mediums and assessment of those mediums with the two dimensions.

\begin{table}
\centering
\begin{tabular}{|c|c|c|c|}
\hline
\textbf{Medium} & \textbf{Accessibility} & \textbf{Portability} \\
\hline
\textbf{Smartphone} & High & High \\
\hline
\textbf{Tablet} & High & High \\
\hline
\textbf{Computer} & Medium & High \\
\hline
\textbf{Network} & Low & Low \\
\hline
\end{tabular}
\caption{Assessment of Communication Mediums}
\end{table}


### Table 1. Assessment of Four Communication Mediums

<table>
<thead>
<tr>
<th></th>
<th>Paper</th>
<th>Smart Phones</th>
<th>Tablets</th>
<th>Augmented Reality Glasses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility</td>
<td>Accessible</td>
<td>Accessible</td>
<td>Accessible</td>
<td>Less accessible</td>
</tr>
<tr>
<td>Portability</td>
<td>Less portable</td>
<td>Potable</td>
<td>Less portable</td>
<td>Potable</td>
</tr>
</tbody>
</table>

- **Accessibility**

Paper instructions are the most commonly used medium to convey contextual instructions in current practices. In addition, smart phones have become a common tool for daily communication in construction. Tablets are usually used to display building information models at the job site. Compared to those mediums, Augmented Reality (AR) is not as accessible in current practices.

- **Portability**

In terms of portability, AR glasses and smart phones are portable in that laborers can get augmented information simply by wearing glasses, and smart phones can be waist-mounted or be put in laborers’ pockets. Paper instructions and tablets are not as portable mainly due to their size.

### 3.2 Engineering Solutions: Develop Prototypes for Each Delivery Method

Based on the discussions in section 3.1, this section will further illustrate on the details about the four communication mediums and how the mediums will be applied in the three sub-processes (i.e., preparing instructions, using instructions, and updating instructions).

#### 3.2.1 Paper

The paper instructions will follow the format as shown in **Figure 1**.

**Preparation Instructions:** Work instructions will be prepared by superintendents and/or foremen prior to the day when a laborer performs a certain task.

**Using Instructions:** Each day before laborers start their work, they need to go over the work instructions to make sure they understand the contexts of their task. In addition, the laborers should get the right tools, equipment and safety measures according to the given work instructions.

**Updating Instructions:** Since the paper instructions are designed to be interactive with construction laborers. Construction laborers, once they identify any changes of contexts at the job site, can provide information on the paper instructions when they give the instructions back to superintendents and/or foremen at the end of each day.

#### 3.2.2 Smart Phones or Tablets

Smart phones or tablets, when used as the communication medium for delivering work instructions, need to have an BIM-based application, which will be developed based on the work instruction template. The application can display details about the building elements.

**Preparation Instructions:** Work instructions will be prepared and customized into electronic format via an application on smart phones or tablets.

**Using Instructions:** Laborers will receive and review work instructions. In the case of using smart phones, it is convenient for laborers to refer to the instructions as they need it because they can carry smart phones all the time. When using tablets, laborers can go to a static work station to get
the tablets or superintendents and/or foremen carry tablets to provide references for laborers. Tablets usually have better display effects than smart phones in terms of showing details of model elements.

**Updating Instructions**: Smart phones or tablets make it easier for laborers to report on changes of contexts by simply taking pictures or providing text descriptions.

### 3.2.3 Augmented Reality Glasses

Augmented Reality can be obtained by transmitting information to laborers through AR glasses.

**Preparing Instructions**: Work instructions will be prepared on the backend server and transmitted in a customized format as tag information attached to the mixed virtual and real scenes.

**Using Instructions**: Tag information (either text information or virtual building parts) will pop up to provided necessary contexts when a laborer is working on a certain task.

**Updating Instructions**: AR glasses can help capture changes of contexts.

### 3.3 Validate Delivery Methods with Industry Collaborators

The above-mentioned delivery methods will be validated through case studies. **Table 2** lists the metrics planned to be collected for both a quantitative and qualitative analysis.

**Table 2. Metrics Evaluating Different Delivery Methods of Work Instructions**

<table>
<thead>
<tr>
<th></th>
<th>Qualitative</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Preparing Instructions</strong></td>
<td>How difficult is it to prepare the instructions? (Very difficult, Difficult, Normal, Easy, Very Easy)</td>
<td>Time it takes to prepare the instructions</td>
</tr>
<tr>
<td></td>
<td>How difficult is it to convey the instructions to workers? (Very difficult, Difficult, Normal, Easy, Very Easy)</td>
<td>Time it takes to convey the instructions</td>
</tr>
<tr>
<td></td>
<td>How relevant is the information to their tasks at hand? (Very relevant, relevant, slightly relevant, not relevant at all)</td>
<td>Extra cost it takes to prepare the instructions</td>
</tr>
<tr>
<td><strong>Using Instructions</strong></td>
<td>How relevant is the information to their tasks at hand? (Very relevant, relevant, slightly relevant, not relevant at all)</td>
<td>Time it takes to get contextual information from the instructions</td>
</tr>
<tr>
<td></td>
<td>How difficult is it for workers to get related contextual information from instructions? (Very difficult, Difficult, Normal, Easy, Very Easy)</td>
<td># of requests for information</td>
</tr>
<tr>
<td></td>
<td>How difficult is it for workers to understand the instructions? (Very difficult, Difficult, Normal, Easy, Very Easy)</td>
<td></td>
</tr>
<tr>
<td><strong>Effects of using instructions</strong></td>
<td>How helpful are the instructions for workers in terms of performing tasks? (Extremely helpful, Very helpful, Moderately helpful, Slightly helpful, Not at all helpful)</td>
<td># of change orders</td>
</tr>
<tr>
<td></td>
<td>How helpful are the instructions for workers in terms of dealing with changes? (Extremely helpful, Very helpful, Moderately helpful, Slightly helpful, Not at all helpful)</td>
<td># of rework</td>
</tr>
<tr>
<td></td>
<td>How helpful are the instructions for workers in terms of addressing their concerns? (Extremely helpful, Very helpful, Moderately helpful, Slightly helpful, Not at all helpful)</td>
<td># of safety incidents</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Productivity rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Estimated cost vs. actual cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Estimated schedule vs. actual schedule</td>
</tr>
</tbody>
</table>
As shown in Table 2, qualitative and quantitative metrics are categorized into three sub-processes. For qualitative analysis, semi-structured interviews will be conducted to collect feedback from construction laborers regarding those listed qualitative metrics. Besides, the research staff will work closely with the construction team to collect quantitative metrics.

4 Expected Results: Findings, Contributions, and Impact on Practice

This research is intended to convey contextual information to construction laborers with effective delivery methods. In line with this final goal, this research will contribute in the following ways:

From the theoretical aspect, this research performs thorough analysis of construction contexts and analyzes how to utilize different mediums empowered by information technologies to convey meaningful contextual instructions to construction laborers.

From the practical aspect, this research investigates different communication mediums for delivering contextual work instructions, and formulate delivery methods as in three sub-processes (i.e., preparing instructions, using instructions and updating instructions). The delivery methods will be compared throughout case studies. As a result, the research will provide effective delivery methods of contextual work instructions for construction laborers.

5 Research Milestones and Risks

The research milestones are as follows.

- By September 30th, 2018, formulate each delivery methods of work instructions with details about how to carry out each sub-processes with a certain communication medium;
- By January 31st, 2019, finish developing prototypes for each delivery method;
- By March 1st, 2019, finish conducting first-round case study with industry collaborators;
- By March 31st, 2019, host a workshop to disseminate the research results; and
- By May 1st, 2019, prepare a journal paper which is ready for publication.

One major risk for this research is that collecting quantitative metrics in the construction industry has always been difficult. To overcome this risk, the research staff has to work closely with the industry collaborators and may appoint special personnel to collect the metrics. In addition, the research staff will explore applications on the market which may be used to track quantitative data.

6 Industry Involvement and Next Steps

For validation, the research staff will collaborate with Shanghai Construction Group (SCG) to conduct case studies. Since this research compares four delivery methods with a certain communication medium, there will be four test groups, each of which will apply one delivery method. To control other variables, those four test groups will be performing the same task within the same time frame. In addition, the test groups will be set up in different projects so as to ensure the generality of the validation process. Furthermore, this research will try to get more industry collaborators involved in the validation process.

7 Budget

Total funds requested: $ 51,978.