

## **Annual Project Report to the National Science Foundation (1 September 2011 – 31 July 2012)**

**Project Title: Flexible Decision-making in Response to Disruptive Events on Construction Sites**

**PI: Cindy L. Menches, Ph.D., P.E.**

**Co-PI: Dror Ben-Zeev, Ph.D.**

**Awardee: Illinois Institute of Technology**

**Award Number: CMMI-1100514**

**Program Officer Name: Konstantinos Triantis**

### **1. What people have worked on the project?**

The following university programs and organization partner for the collaborative research on Flexible Decision-making in Response to Disruptive Events on Construction Sites:

#### **1.1 Illinois Institute of Technology:**

**Cindy L. Menches, Ph.D., P.E.;** Assistant Professor, Department of Civil, Architectural, and Environmental Engineering, Construction Engineering and Management Program

Role: Principal Investigator

How this person participated in the project: Dr. Menches is the Principal Investigator for the research. Dr. Menches leads the research and developed the theory upon which the award was based. She has been involved in every detail of the study since the proposal was submitted in 2010. She has been actively involved with the design of the surveys and questions, selection of the data collection devices, collecting data, reviewing data, data analysis, data interpretation, and theory development. Dr. Menches and Ms. Chen (GRA) have spent a significant number of hours discussing the research and its findings and ultimately revising the theory and the survey questions. Her involvement has been critical to the success of the research.

**Scott Morris, Ph.D.;** Associate Dean and Associate Professor, College of Psychology

Role: Senior Personnel

How this person participated in the project: Dr. Scott Morris is a Senior Personnel and is providing consultation and advice on study design, statistical analysis, and questions that are uniquely psychological in nature. He has assisted with the interpretation of results of the research so far, and has suggested methods for adjusting the "path forward" based on the research questions and research findings. Dr. Morris is supported by Summer Salary from the NSF grant and has been a very valuable team member.

**Juan Chen, Ph.D. Candidate**

Role: Graduate Student

How this person participated in the project: Ms. Juan Chen is a Ph.D. candidate and the graduate research assistant for the study. Ms. Chen has been involved in every detail of the study since its initiation in Sep. 2011. She has assisted with the design of the surveys, programming the data collection devices, collecting data, downloading data, database management, data analysis, data interpretation, and theory development. Ms. Chen and Dr. Menches (PI) have spent a significant number of hours discussing the research and its findings and ultimately revising the theory and the survey questions. Her involvement has been critical to the success of the research.

#### **1.2 Additional University that Partnered with Illinois Institute of Technology:**

**Dror Ben-Zeev, Ph.D.;** Assistant Professor of Psychiatry, Dartmouth Medical School; Director, Thresholds-Dartmouth Research Center

Role: Co-Principal Investigator

How this person participated in the project: Dr. Ben-Zeev is primarily providing consulting services to the PI, Senior Researcher, and graduate students. He offers advice about the data collection tools, methods for successfully recruiting participants, troubleshooting data collection digital devices, best practices and lessons learned for conducting an Ecological Momentary

Assessment study, and data analysis. I would estimate the hours spent on consulting services for the first year to be about 40 hours.

## **2. What other organizations have been involved as partners?**

The following other organizations have been involved in the research on Flexible Decision-making in Response to Disruptive Events on Construction Sites:

### **2.1 Professional Trade Association:**

Electrical Contractors' Association of City of Chicago, Frank T. Peters, Chief Operating Officer

Partner's contribution to the project: In-kind support

More detail about partner and contribution: The Electrical Contractors' Association (ECA) of the City of Chicago is a professional trade association that represents union electrical construction companies. The PI and GRA met with Frank Peters (Chief Operating Officer) to explain the research and seek the ECA's assistance in marketing the research and locating companies that would be willing to participate. Through this network of contractors, the PI has been able to successfully recruit sufficient companies to participate. Also, through word-of-mouth among the contractors that belong to ECA, companies know about the research, thus making it easier for the PI to locate participant-companies. We anticipate that this support will continue and that the PI will ultimately make one or more presentations about the aggregated findings as the research progresses.

## **3. Activities and Findings**

### **3.1 Describe the major research and education activities of the project**

During the first year of the research project, the researchers made progress towards their two principal objectives: (1) Determine how, and with what outcome, construction workers adjust plans using improvisation in response to disruptions and plan deviations on the jobsites, and (2) Establish the conditions that facilitate or hinder improvisational effectiveness under circumstances on the jobsite. The following research activities were performed, along with relevant findings:

- (1) Conducted Two Pilot Studies:** A small pilot study was conducted in July 2011, prior to receiving the funding for the research. The purpose of the first pilot study was to test the feasibility of the research method (i.e., collecting momentary data from construction workers using digital devices). The first pilot study was conducted following several months of developing questions for the questionnaire that was provided to workers on personal digital assistant (PDA). The questionnaire was designed to capture the worker's context, decisions, improvisational actions, and emotions.

Following the first pilot study, the questionnaire was modified extensively and a second pilot study was conducted in January 2012 to further test the data collection method, questions, and instruments. For both pilot studies, electrical construction workers from the Chicago metropolitan area were recruited to participate. For the second pilot study, one electrical construction company nominated a large project for the study, and as a result, six journeymen electricians and three foremen were selected from among over 35 electrical construction workers to participate.

The data collection instruments included three questionnaires: one to capture baseline assessment data, one to capture ecological momentary assessment (EMA) data (i.e., data collected in the natural work setting multiple times per day), and one to collect data from the exit interview. The baseline assessment was designed to collect subjects' basic information, such as demographics, professional background, and personal characteristics. The EMA survey was designed to collect data on the construction workers' improvised decisions and actions, particularly when they experienced a disruption. The responses to the questions provided insight into the type of disruption workers encounter, types of task performed before and after the disruption, whether the disruption required a change to the task, location or method used to perform the task, and the emotional state of the worker following the disruption.

The data collection cycle involved (1) training the workers to use the digital devices (i.e., PDA), (2) collecting self-reports (i.e., momentary assessments) on the PDA from each worker for one week, (3) retrieving the devices and downloading the data, (4) studying the data and creating printouts for the exit interviews, and (5) conducting the exit interviews. Hence, the first stage of the data collection process involved training the workers on how to use the digital devices to complete the momentary assessments (i.e., surveys) and what to do if the device failed. The training occurred on Monday morning of Week 1 just prior to the start of work (around 6:30 AM). Two researchers met with the workers (i.e., participants), with one researcher explaining the procedures while the other researcher demonstrated the operation of the device. The researchers explained the procedures and asked the workers to complete one trial survey on the device. As the workers conducted the trial run, the researchers explained each question and demonstrated how to make their selection from among the multiple choice questions.

Following the training, the workers placed the PDA in a carrying case, attached the carrying case to their belt, and went to work. The devices were programmed to send five alarms per day to the workers between the hours of 7:30 AM and 3:00 PM. An alarm was programmed to beep at a random moment within five 1.5-hour windows (7:30-9, 9-10:30, 10:30-12, 12-1:30, and 1:30-3). The alarm sounded for five minutes to give the workers enough time to complete their task, determine whether it was safe to respond, and then respond to the survey. The digital survey was designed to permit the worker to respond to all of the questions in three minutes or less. At the end of each day, the workers returned the devices to the construction office, where they were plugged into an electrical source to be charged overnight. The next morning, the workers retrieved their device and continued responding to alarms. At the end of the week, a researcher returned to the site to collect the devices from the workers. The following week, the researchers conducted exit interviews to discuss the results of the data collection effort with the workers.

During the exit interviews, the three foremen indicated that they “were never disrupted” and, therefore, the data collected from them was “bad data” (i.e., it did not capture the phenomenon we were interested in). In questioning the foremen further, it became apparent that the foremen believed that a disruption was only the result of an extreme event, such as a generator failure or a transformer explosion. Small, moment-to-moment disruptions, such as other trades in the way or missing materials, were simply “part of the job.” They viewed their job duties as “putting out fires all day.” It was clear from the exit interviews with both workers and foremen that we were able to capture the phenomenon of disruptions and improvised actions from the workers but that the foremen data collection effort would require a different approach. Thus, data collection from the foremen was postponed while we prepared to conduct a focus group with the foremen to learn more about their disruptions, which observationally appeared to occur chronically all day long. Hence, the crew member questionnaire was modified and full data collection from journeymen and apprentices began in late January 2012.

- (2) Collected data from crew members (Phase 1):** Between January and May 2012, fourteen electrical construction workers (7 journeymen and 7 apprentices) from six different jobsites participated in the study. The procedures for collecting data from the workers were identical to those described previously for the pilot studies. The researchers typically collected data from two workers (one journeyman and one apprentice) during every two-week cycle. The researchers downloaded the data at the end of the data collection week, studied the data, and developed specific questions for the exit interview during the following week. Through numerous discussions with the participating workers, the researchers were able to better define improvisation in a construction context (i.e., “a deviation from the plan”) and to develop a way to measure improvisation: a change in the task, location, time, and/or method. That is, the definition of a “plan” is a “specific task performed in a specific location at a specific time and using a specific method.” If any of these four factors changed, then an improvisational decision and action occurred. Based on this key finding, the researchers created an index (Table 1) to more accurately measure the degree of improvisation that occurred following a disruption on a construction site. This new metric will be implemented in the next phase of the research.

### **3.2 Describe the major findings resulting from these activities**

- (1) Results from the January 2012 Pilot Study:** Data was collected from six journeymen electrical construction workers. Unfortunately, one digital device failed, and that worker's data was lost, so analysis was performed on the remaining five workers' data. The analysis consisted of a between-persons analysis of the aggregated data as well as within-person individual analyses.

The analyses revealed that there was a group-level positive correlation between experiencing a disruption and initiating an improvised decision and action, meaning that, as a whole, this group of construction electricians on this jobsite tended to improvise their decisions and actions when they experienced a disruption. However, three of the electricians tended to improvise frequently when disrupted while the other two workers did not. Furthermore, certain types of disruptions – anecdotally – triggered certain types of improvisation. For example, interruptions by another person and disruptions caused by a lack of tools/materials/equipment often caused the journeymen to work on an entirely different task (i.e., execute a substantial or total improvisation). Additional data collection and analysis from other workers on other jobsites, using the EMA technique, might provide more definitive evidence that specific types of disruptions trigger specific types of improvisational decisions and actions.

The analysis also revealed that the workers' emotions fluctuated throughout the day and week, and a negative group-level correlation was identified between disruptions and two emotions – determined and interested – where the levels of determination and interest tended to decline following a disruption. No group-level correlation was identified between disruptions and negative emotions. But, clearly some of the workers experienced momentary increases in their negative emotions (e.g., increases in their level of irritation), suggesting that not all workers react in the same (perhaps calm) way to workflow disruptions. Furthermore, specific workers tended to experience more frequent disruption-related momentary changes in emotions, possibly suggesting a three-way relationship between personality, reactions to disruptions, and changes in emotions, which could be examined further by collecting additional data from other workers on other jobsites.

Hence, an EMA technique provides a single method for collecting multiple data points from multiple construction workers at multiple points in time, thus providing researchers with a flexible way to examine not only the trends in processes and behaviors but also specific instances of phenomena that occur as “consequences of causal strings of unique events.” The EMA technique, as a result, provides a novel way to identify the impact of such unique events on worker decision-making and performance.

- (2) Results from the Phase 1 Data Collection:** Data Analysis for the Phase 1 data collection effort is currently in progress.

During the Phase 1 data collection, the researchers asked workers to identify (on the momentary surveys) whether they were disrupted and whether they improvised a decision and action. Specifically, the “degree of improvisation” performed by a respondent was identified through the following questions: (When disrupted) How different is your new task (following the disruption) from your planned task? And (when not disrupted) How similar is your current task to your planned task? The possible answers to these questions included: (1) I am performing the same task in the standard way, (2) I am performing the same task in a non-standard way, (3) I am performing an entirely different task in the standard way, and (4) I am performing an entirely different task in a non-standard way. These questions and responses explored how significantly the disruptions (or lack of disruptions) impacted a worker's ability to complete the assigned tasks. The underlying assumption is that the decision to select a new task that requires a creative (i.e., non-standard) method for completing the task (Response 4) is more improvisational than simply working on the same task as planned and performing that task using the typical methods (which requires no improvisational decisions or actions) (Response 1). Hence, the ordering of the responses reflects the increasing degree of improvisational decisions and actions that might be

taken either involuntarily (e.g., when disrupted) or voluntarily (e.g., when not disrupted) in order to remain productive, where the ordering of improvisation can be thought of as no improvisation (Response 1), minor (Response 2), moderate (Response 3), and major improvisation (Response 4).

As the Phase 1 data collection was concluding, the researchers re-defined their concept of improvisation as “a deviation from the plan” because in the construction industry, the primary goal is to follow the plan in order to meet a specified time constraint (completion date). Consequently, they also defined a “plan” as a “specific *task* performed in a specific *location* at a specific *time* and using a specific *method*.” This revised definition of a “plan” thus greatly simplified the measurement of a deviation from the plan (i.e., improvisation). Phase 2 will use this new definition as the basis for measuring the degree to which journeymen and foremen improvise.

Table 1 distinguishes between different degrees of improvisation on the jobsite. Although a deviation from the plan is measured as a change to the task, location, time, method or any combination of these factors, the decision was made to measure time as a single day (essentially, *today*). This decision was made after interviewing several foreman to determine how they develop their work plan (i.e., typically they know what they want the crew members to work on each day and can measure whether the work was completed). Likewise, workers measure progress by whether they have completed the assigned set of tasks for a single day (i.e., each day). Consequently, the degree of plan deviation (i.e., improvisation) can be measured by the other three factors that constitute the daily plan: task, location, and method (as shown in Table 1). Hence, a score (i.e., degree) was assigned to each combination, where a change in task was considered more severe than a change in location, which was considered more severe than a change in method. The degrees identified in the table reflect the increasing severity of the degree of improvisation that might be implemented on the jobsite as a result of a disruption. Based on the scores, the degree of improvisation (degree of plan deviation) can be scored from 0 = No improvisation to 7 = Change in task, location, and method.

Based on a summary analysis of the 14 subjects' data collected during Phase 1, the researchers discovered that 50% of the improvisational decisions were made by the *foreman only*, 20% of the improvisational decisions were made *jointly by the foreman and crew member* together, 15% of the improvisational decisions were made by the *crew member only*, and 15% of the improvisational decisions were ascribed to “other” combinations. In other words, the foreman was involved in the majority of the improvisational decisions when a task disruption was experienced. However, an important distinction was made that will be investigated further in Phase 2 of the data collection: while the foreman makes most of the improvisational decisions, these decisions must be executed by the crew member. Hence, in construction, it is difficult (or nearly impossible) to decouple the decisions made by the foreman and the actions executed by the workers. Improvisation in construction is a multi-level process that involves both the foreman and the crew member. Early indications point to the foreman making most of the decisions about changes to the *task* and changes to the *location* (i.e., plan improvisation) while the worker is often given the latitude to improvise the *method* for completing the new task (i.e., execution improvisation).

While it is clear that improvisation in other fields (such as fire response, emergency management, and new product development) also involves multiple parties (a decision-maker who is different from the implementer), this two-level structure of improvisation has never been specifically addressed. However, in construction, this connection cannot be ignored; as a result, the researchers will address improvisation that is performed by the foreman (i.e., plan improvisation) as well as improvisation that is performed by the crew members (i.e., execution improvisation), and the findings for these two groups and levels is expected to be different.

- (3) **Next Step:** The next step of the research is to conduct a focus group discussion with the three foremen from the January pilot study. The questions that need to be addressed in the focus group meeting are:

- Definitions of (or vocabulary for) “disruption” for the foreman (especially “task installation disruption”)
- Definition of “plan” as a specific task performed in a specific location at a specific time using a specific method; is anything missing?
- Validating time: validate that the foremen develop weekly and daily plans; verify that both mental and written plans are typical.; if they have a daily plan, even if it is vague, then time can be left out of the plan metric because time is one day
- Discuss the index used to measure degree of improvisation (i.e., deviation from plan)
- Ask them to review three measures of the “effectiveness” of improvisation and decisions: (1) most closely follows the original plan, (2) improves the flow of work, and (3) allows the crew member to work productively (plus anything else they add)
- How to capture “How and/or why they improvise” and which word (HOW or WHY) makes it easier to answer the question. Do they prefer to use a written paper “journal” to respond to this question or voice record it or text it into the PDA
- What is the best way to collect data from them (paper v. PDA or a hybrid method)
- A review of the PDA device and how it works

Following the foreman focus group, the researchers will complete the revisions to the foreman questionnaire and begin collecting data from the foremen. Phase 2 data collection is expected to occur from Sep 2012 through Dec 2012 and may be extended if needed.

**Table 1.** Index for the Measurement of Degree of Improvisation

Combo	TIME	TASK	LOCATION	METHOD	Same or Diff	DEGREE
1	Same	Same	Same	Same	SAME	0
2	Same	Same	Same	Different	SAME	1
3	Same	Same	Different	Same	DIFF	2
4	Same	Same	Different	Different	DIFF	3
5	Same	Different	Same	Same	DIFF	4
6	Same	Different	Same	Different	DIFF	5
7	Same	Different	Different	Same	DIFF	6
8	Same	Different	Different	Different	DIFF	7
9	Different	Same	Same	Same	NA	
10	Different	Same	Same	Different	NA	
11	Different	Same	Different	Same	NA	
12	Different	Different	Same	Same	NA	
13	Different	Same	Different	Different	NA	
14	Different	Different	Same	Different	NA	
15	Different	Different	Different	Same	NA	
16	Different	Different	Different	Different	NA	

#### 4. Training and Development

One full-time graduate research assistant, Ms. Juan Chen, is working on the project and has been fully supported through research funds. Ms. Chen formerly worked with the PI on an applied research project. Hence, the current shift to theoretical research involved a significant change in the way the research was conducted and conceptualized. Because theoretical research has a strong emphasis on discovery and creation of new knowledge, rather than on production of a definitive product, Ms. Chen has been given the latitude to intensely question the research assumptions, revise the theory based on new discoveries, and change directions to better respond to the research questions. A great number of hours have been spent in simple conversation about what has been observed and how these observations differ from reports from other researchers who have investigated improvisation in other fields. Ms. Chen was an unofficial teaching assistant for the PI's spring class, and she will be allocated lecture time during the fall

and spring semester to provide her with the opportunity to hone her teaching skills. In addition to Ms. Chen, four international visiting students have worked on the project. Each of these four students studied under the direction of the PI for 4-6 months, performing various tasks, such as programming the digital devices, developing the website, organizing the data, and performing summary statistical analysis.

## 5. Outreach Activities

No outreach activities have been performed yet.

## 6. Publications and Products:

### 6.1 What have you published as a result of this work:

#### (a) Journal Publications:

Menches, C. L. and Chen, J. (2012). Using ecological momentary assessments to understand a construction worker's daily disruptions and decisions. *Construction Management and Economics*, In press.

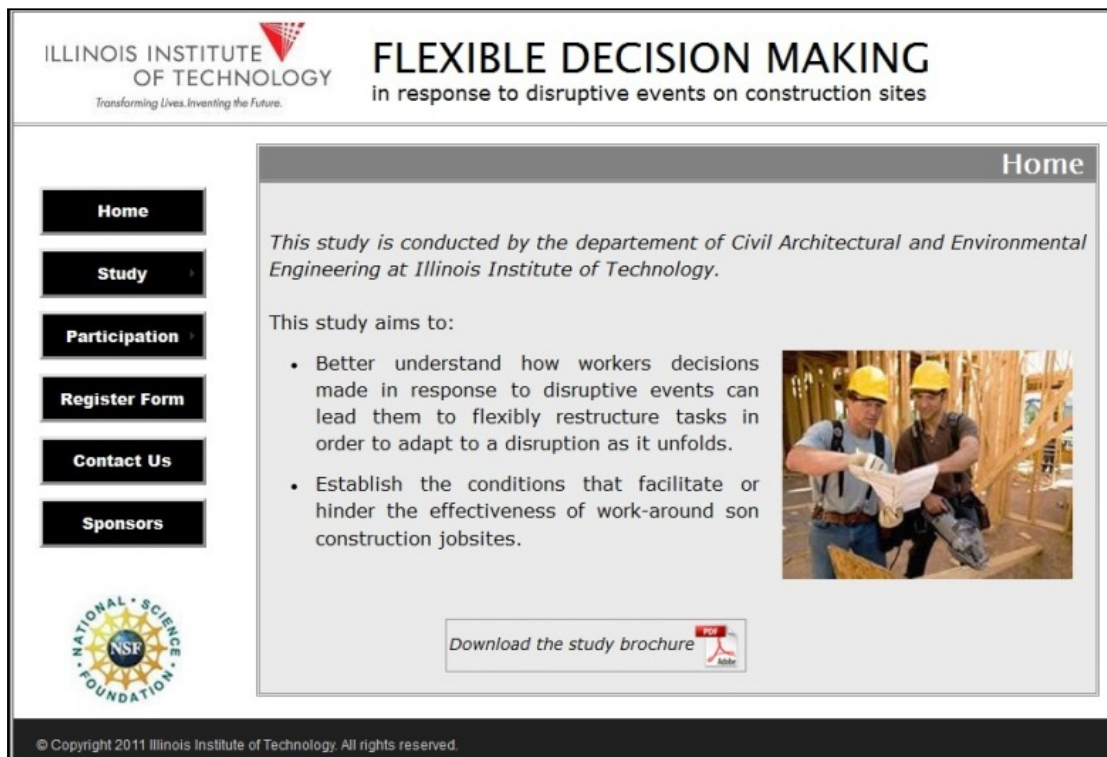
Menches, C. L. and Chen, J. (2012). A diary study of the disruption experiences of crew members on a jobsite. Submitted to *Journal of Management in Engineering*, June 2012.

### 6.2 What Web site or other Internet site have you created

#### (b) Internet Dissemination:

A website was created for the purpose of introducing the study and recruiting participants. The URL is:

<http://mypages.iit.edu/~cmenches/flexible-decisions/index.html>



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# FLEXIBLE DECISION MAKING

in response to disruptive events on construction sites

Home

Home

Study

Participation

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This study is conducted by the department of Civil Architectural and Environmental Engineering at Illinois Institute of Technology.

This study aims to:

- Better understand how workers decisions made in response to disruptive events can lead them to flexibly restructure tasks in order to adapt to a disruption as it unfolds.
- Establish the conditions that facilitate or hinder the effectiveness of work-around son construction jobsites.

Download the study brochure 

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Figure 1. Home page of the project website

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# FLEXIBLE DECISION MAKING

in response to disruptive events on construction sites

**Register Form**

First name :

Last name :

Age :

Company name :

Position :

Email :

Phone number :

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**Figure 2.** Registration page for the project website

### **6.3 What other specific products (databases, physical collections, educational aids, software, instruments, or the like) have you developed?**

A database containing all of the collected data has been developed but is being scrubbed for pending data analysis.

## **7. Contributions**

### **7.1 Contributions within discipline**

One key contribution of this research to the field of construction research is its use of a well-established momentary research method that has been used broadly in other fields, especially psychology and mental health, but has never been applied to the field of construction. The method – called the Ecological Momentary Assessment method – is designed specifically to capture momentary work experiences in natural work settings, thus providing researchers with rich, detailed information about the daily challenges experienced by construction workers during the course of performing their tasks. This novel data collection method is minimally disruptive to workers and allows workers to identify their decision process “in the moment.” Such a method makes it possible to investigate a vast array of phenomenon experienced by a worker during the course of performing daily work, thus opening the door to the development of new theories about rapid decision making and subsequent actions that influence workflow on construction sites.

### **7.2 Contributions within other disciplines**

A principal contribution to the field of organizational improvisation is our current focus on collecting data from the improvisational decision-maker (i.e., the foreman) as well as the improvisational implementer (i.e., the crew member). While many other fields improvise under similar circumstances – where the decision-maker is often different from the implementer – no research has attempted to address this multi-level structure of improvisation in organizations. Yet, multi-person improvisation has been acknowledged in numerous studies and appears to be widespread. Until now, the field of organizational improvisation has not directly addressed this



distinction and perhaps one reason for this lack of attention has been insufficient tools to capture this phenomenon. Using the EMA approach, the researchers will attempt to better understand how the improvisational decisions of the foreman impact the improvisational actions of the crew members, and how this connected process impacts performance.

### **7.3 Contributions to human resource development**

The primary contribution of this project to the development of human resources is through the involvement of graduate students in the research and the development of the PI's skills as a researcher. Because this topic – improvisation in construction – is unique and has never been studied before, the research has evolved, new discoveries have been made, and theories have been revised. This evolutionary process has clearly had a positive impact on the graduate research assistant and the PI, who have spent numerous hours in conversation about the observations and how the observations are the same or different than expected and the same or different than other research. Furthermore, the involvement of four international visiting master's students has opened the door to their potential to become researchers in their countries in the future.

### **7.4 Contributions to resources for research and education**

The primary contribution to future research efforts is the addition of new data collection devices, along with data collection partnerships with external companies that can supply the software and consulting to improve the data collection process. By testing numerous devices, making adjustments, and exploring commercial partnerships with external companies, the researchers on this project have opened the door to other researchers at the Illinois Institute of Technology to apply the EMA method to their research questions. Furthermore, research partnerships between the Department of Civil Engineering and the College of Psychology – which is atypical – has created a vast array of potential human-centered research that would not otherwise be possible.

### **7.5 Contributions beyond science and engineering**

The contribution of the project to public welfare is by advancing how the construction industry understands and plans for the use of improvisation as a complement to detailed planning and plan-following as a means to control workflow variability. Fundamental research on the use of improvisation on construction sites has never been conducted, and given the size of the construction industry, the research contributions (i.e., positive and negative impacts of improvised actions) are expected to directly impact the efficiency of the U.S. construction workforce, and as a result, the economy as a whole. The contributions of the research include (1) a transformation of the way workers, foremen, and construction managers plan for, accommodate, and manage disruptions on the jobsite; and, (2) an increase in efficiency of construction workers through a corresponding reduction in workflow variability.