ILLINOIS INSTITUTE OF TECHNOLOGY

Working Paper

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10/7/2013

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ABSTRACT
This article examines the relationship between specific construction project characteristics and the degree and speed that the foremen are able to improvise in response to disruptive events on the jobsite. Specifically, characteristics such as the number of crew members working under the supervision of a foreman, the occupancy status of the project (i.e., occupied or unoccupied) during construction, the stage of completion of the project, and the levels of turbulence, time pressure, cooperation, collaboration, and organization, were examined. Using a multilevel regression modeling approach, an analysis of 244 disruptions reported by 50 foremen was conducted to determine whether the construction project characteristics could predict more or less improvisation and faster or slower improvisation by the foreman. The findings indicate that on construction projects that are rated by the foremen as more organized, the foremen can make more modest improvised decisions to resolve a disruption, but that on construction projects that were rated by the foremen as more collaborative (i.e., involved joint decision-making), a greater degree of improvisation was deployed. In addition, it was found that on sites that were rated by the foremen as more cooperative (i.e., involved greater willingness to help each other), the foremen required more time to improvise their decisions.

KEYWORDS
Foreman, job site characteristics, decision-making, improvisation, disruptions

JOBSITE CHARACTERISTICS AND DECISION-MAKING ON CONSTRUCTION SITES

When thinking about what constitutes a difficult construction job site, the characteristics that may immediately come to mind are disorganization, turbulence, and lack of cooperation and/or collaboration among the major parties. Conceptually it might make sense that these difficult sites might require the foremen to take more drastic improvised measures to resolve disruptions, and those decisions would likely take longer than on a less difficult job site. Yet no study has specifically examined the relationship between jobsite characteristics and the need for fast improvised decisions within the construction industry.

The degree and speed of the foremen's fast improvised decision-making process is of utmost importance because numerous researchers have demonstrated the key role that improvisation plays in work environments. Ciborra (1999) noted that improvisation plays a ubiquitous and fundamental role in organizations because, without the ability to improvise, many organizations would be unable to flexibly adapt their actions to meet the time constraints often imposed on its employees. In addition, it was found that improvisation can fill voids in planning and create opportunities for breakthroughs in performance in turbulent industries (Brown and Eisenhardt 2002; Leybourne 2010; Miner et al. 2001). Thus this article seeks to identify whether there are project characteristics that can influence the improvisational decisions of construction foremen. A unique aspect of the research was the investigation of the phenomena (i.e., improvised decision-making) at two levels of analysis: the Level 1 analysis involved evaluating the influence of the type of work flow disruption and project characteristics on the degree and speed of improvised decision-making, while the Level 2 analysis identified the potential influence of individual foremen traits on the degree and speed of improvisation. Because the research involved collecting data on multiple disruptions experienced by each of the 50 foremen, the Level 2 model controlled for the within-person variability in decision-making by each foreman. Consequently, the focus of this article is on

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the Level 1 analysis that investigated the relationship between the type of disruptions and project characteristics and the degree and speed that the foremen improvised decisions.

IDENTIFICATION OF JOBSITE CHARACTERISTICS THAT INFLUENCE IMPROVISATION

Jobsite Factors that Influence a Foreman's Improvisational Decision-making Options

To develop an initial sense of the jobsite characteristics that are likely to influence the foreman's need and ability to improvise fast decisions, the authors first conducted a half-day focus group with three construction foremen. This focus group was followed by informal discussions with individual foremen in their natural job setting (i.e., the site). According to foremen, the major characteristics of a jobsite that could potentially account for the degree to which foremen must improvise and the speed at which they *can* improvise include (in no particular order):

1. The **size of the crew** working under a foreman's supervision
2. The **stage of the job**; for example, the job was just beginning, in the middle, or concluding
3. The **type of project**; specifically, was the project a specialty building such as a hospital, or was it a non-hospital project
4. The **occupancy status** of the building during construction; for example, was the project occupied by tenants or not occupied by tenants.
5. The amount of **turbulence** or chaos on the jobsite
6. The **time pressure** that the foremen felt in completing their work
7. The overall level of structure and **organization** of the jobsite
8. The **level of cooperation** on the jobsite between the major parties, where cooperation involved a willingness to help each other
9. The **level of collaboration** on the jobsite between the major parties, where collaboration involved joint decision-making of the parties

Scholarly Literature on Relevant Jobsite Characteristics

Organization. There are many factors that could determine the perceived level of organization and structure on a jobsite. These could include the cleanliness of the site, material staging, the congestion of the trades, or the level of discourse and communication between the trades on the site.

Previous studies have linked a disorganized work area to increased time in attempting to locate items in that workplace (Williamson, 1998; Asher, et al. 2013). While Williamson looked at messy desks and Asher examined different levels of clutter interfering with visually locating specific items, the same concept could apply to a construction jobsite where materials are scattered everywhere and there is garbage and debris in need of cleaning.

One study examined the causes of cognitive overload in the workplace and found that one cause was "inadequate workplace infrastructure to help reduce the need for planning, monitoring, reminding, reclassifying information, etc..." (Kirsh, 2000). It might not be a stretch to assume that within the foremen's perception of the overall organization of the jobsite, they were including the workplace infrastructure that could either make performing their job easier or harder.

Cooperation. There are varying views and emphases on "what defines cooperation" and "what is the opposite of cooperation." One scholar defined conflict as the opposite of cooperation (King, et. al, 2009). On construction jobsites, this conflict (i.e. lack of cooperation) can include, among other factors: willfully getting in each other's way, performing ones' work in a way that may interfere with the work of another trade, and ignoring any potential synergies between trade installations that may exist. Pelled, Eisenhardt, and Xin isolated conflict into *task conflict* and *emotional conflict* (Pelled, Eisenhardt, and Xin, 1999). Anecdotes of numerous foremen tend to support tales of disagreements about methods to do the work and also on interpersonal conflicts with other foremen they don't personally like.

One common belief is that cooperation can be used as a tool for achieving the goals of the cooperating parties (Chatman, 1998; Milton & Westphal, 2005). Perhaps most important to the concept of *speed of decision-making* of the foremen in this study was the work by Campion, Medsker, & Higgs that defined cooperating in terms of listening to other's ideas and also working to obtain a group consensus (Campion, Medsker, & Higgs, 1993). This may explain one finding of this research that while increased levels of cooperation resulted in a decrease in the degree of improvisation required, the speed of improvisation was slower (i.e. the decision making process took longer). This would imply that, given that the other trades are cooperating with them, foremen's improvised actions don't have to be as extensive, but they do want to be mindful of how their actions will affect the other foremen on the site that are cooperating with them. Many foremen noted that when other trades watched out for them, they returned the favor and tried to make decisions that looked out for those cooperating trades. This may provide a plausible explanation for why the decision-making process took longer when there was increased cooperation.

Collaboration. Just as cooperation had no single definition or agreement among scholars, collaboration is similarly varied. As a starting point, the Merriam-Webster dictionary defines collaborate as; 1. to work jointly with others or together especially in an intellectual endeavor. Friend and Cook's definition (2000) has been frequently cited in academic papers that defines it as 'a style for direct interaction between at least two co-equal parties voluntarily engaged in shared decision-making as they work towards a common goal' (p. 6). In summing up many ideas on collaboration, Kennedy (2011) stated, "Common features in defining collaboration … are goal setting and planning with team members, sharing information, discussing problems and learning from others." Based on these definitions, it can be assumed that the parties on a construction project would benefit from collaborating together to accomplish their goals. A more structured, legal form of collaboration used in the construction industry became known as Integrated Project Delivery (IPD).

In outlining the history of IPD, Nobel (2007) noted that in the United Stated in the 1990's, design-build was increasingly replacing the traditional design-bid-build project delivery method, but "a delivery method known as project alliancing was being used successfully for a number of infrastructure projects in Australia." "This delivery method seeks to improve project outcomes through a collaborative approach of aligning the incentives and goals of the team (Australian Department of Treasury and Finance, ADTF, 2006). Summarizing the history of the arrival of the IPD concept, Kent (2010) noted that "Project alliancing is the model for a new project delivery method that has recently emerged in the United States, commonly referred to as integrated project delivery, IPD". In a similar spirit, it could be understood that greater collaboration, in a broad sense, will increase the degree of improvisation on construction sites because the parties are more willing to accommodate the other trades around them, which will increase their flexibility in how they accomplish their tasks.

An emerging area of research on the concept of collaboration within the construction industry focuses on Building Information Modeling or BIM. According to the Associated General Contractors of America (2006) "BIM is the development and use of a computer software model that is data-rich, object-oriented, intelligent, and parametric digital representation of a facility used to simulate the design, construction, and operation of that facility." Studies have examined the potential benefits of collaborating through the use of BIM on jobsites, such as Eastman (2008), who stated " BIM is not only a tool but also a process that allows project team members an unprecedented ability to collaborate over the course of a project from early design to occupancy. Kent's (2010) work on IPD noted, " IPD attempts to create the collaborative atmosphere required for the most comprehensive use of BIM by aligning the goals of all team members and incentivizing them to work closely together throughout all phases of a project."

Currently, no literature examines how the levels of collaboration might influence the degree of improvisation that would result when the inevitable disruptions occur. Thus this article seeks to fill the void in the industry's knowledge.

MEASUREMENT OF THE JOBSITE CHARACTERISTICS

The jobsite characteristics investigated in this research were gathered from a Foreman Baseline Questionnaire that each of the foremen completed at the end of their participation in this research, and included:

Crew Size: The options for the crew size supervised by the foreman included (1) 1-2 workers, (2) 3-4 workers, (3) 5-6 workers, (4) 7-8 workers, (5) 9-10 workers, and (6) more than 10 workers.

Stage of Job: The stage of the job ranged from (1) very beginning, (2) early stage, (3) middle stage, (4) later stage, and (5) very end.

Type of Project: The type of project was an open ended response, and included responses such as new school construction, occupied hospital renovation, new pharmaceutical facility, and tenant build-out.

Other Characteristics: For the levels of the project's turbulence, time pressure, organization, cooperation, and collaboration, the foremen were asked to provide a rating ranging from (1) low, (2) moderately low, (3) medium, (4) moderately high, and (5) high. These responses were ultimately treated as continuous variables.

CAUSES OF FOREMAN IMPROVISED DECISION-MAKING

Improvised decision-making involves "reworking knowledge to produce a novel action in time to meet the requirements of the situation" (Mendonça and Wallace 2002). Thus, improvisation is "resourceful action" executed in context, where the context is provided by the need to meet daily goals, such as completion of tasks in a sequence to meet time constraints (Mendonça and Wallace 2002). Consequently, improvising involves *deliberate* human actions often driven by time pressure, disruptions, or uncertainty, and it draws upon the intuition, experience, and competence of the improviser within their specific context (Ciborra 1999). Improvisation often results from individuals' abilities to recognize patterns in their daily flow of work and to apply their tacit knowledge to the current situation so that work can proceed. Such fast thinking and acting can augment more careful planning thus providing a mechanism for increasing productivity when work does not proceed as planned.

Improvised decision-making can occur as a spontaneous, creative act, such as when a construction worker changes their work method because they believe that a different (perhaps more creative) work method might result in getting the work completed more quickly or more efficiently. But, improvised decision-making can also occur through necessity, such as when the planned work task cannot be completed as originally planned thus requiring the construction worker or supervisor to develop a new plan "in the moment" to keep the work flowing. The focus of the present study was on the improvisational decisions and actions that resulted from a disruption to the planned work task. Consequently, a list of 18 different disruptions, categorized into six general types of disruptions, was developed from conversations with construction workers and a focus group conducted with construction foremen (Figure 1). The six general types of disruptions (and their frequency reported in this study) include: (1) something or someone is in the way (19.7%), (2) something or someone interrupted the work (29.1%), (3) something or someone is lacking (18.9%), (4) a change of sequence occurred (10.7%), (5) a miscommunication occurred (11.5%), and (6) other (10.2%). Figure 1 identifies the 18 different disruptions used in the current research.

MEASUREMENT OF THE DEGREE AND SPEED OF IMPROVISATIONAL DECISIONS AND ACTIONS

In order to build the theoretical constructs to measure the degree and speed of improvisation, a definition of improvisation (for the purpose of this study) was developed. Thus, improvisation is defined as *a deviation from the plan* (i.e., the planned work tasks). A plan is comprised of four elements including (1) a specific task, performed at (2) a specific time, in (3) a specific location, using (4) a specific work method. When a foremen deviates from the plan, improvisation has occurred, and the two theoretical constructs of degree of improvisation and speed of improvisation can be measured.

The degree of deviation from the planned task, time, location, or method (including a deviation from none, any, or all of these plan elements) was (each) measured by a Likert scale that consisted of: 0 = no deviation, 1 = minor deviation, 2 = moderate deviation, 3 = substantial deviation, and 4 = total deviation. Hence, degree of improvisation was calculated as the weighted, summed deviation scores for task, time, location, and method, where the weight reflected the average contribution of the plan element (task, time, location, or method) to overall improvisation as identified by the study participants (e.g., a *task deviation* may require actions that are twice as improvisational as a *location deviation*).

Time, however, received different treatment than task, location, and work method. Study participants (i.e., foremen) reported on improvisational decisions and actions in the moments immediately following the disruption. Thus, the foremen reported on whether their crew member was assigned to work on the planned task *exactly as planned* in the location *exactly as planned* using the work method *exactly as planned*. Because a change to any of these elements prevented the originally planned work from being completed *at the exact time it was planned* (which was measured as "now"), time was measured as a binary variable: either as "Yes, the exact task was completed at the exact time in the exact location using the exact work method planned" – which was the equivalent of using no improvisation – or as "No, the exact task was not completed at the exact time in the exact location using the exact work method

Category of Disruption	Frequency Reported
Category 1: In the Way	
1. Another trade was in the way	9.8%
2. Materials / tools / trash were in the way	4.9%
3. Lack of access (locked doors / restricted areas)	2.9%
4. Other non-trade people were in the way	2.0%
5. Another crew member was in the way	0.0%
Category 2: Interruption	
6. Other non-trade people interrupted the installation	13.9%
7. Another trade interrupted the installation	12.7%
8. Another crew member interrupted the installation	2.5%
Category 3: Lacking	
9. Lack of materials / tools / equipment	9.4%
10. Lack of information / directions / communication	7.0%
11. Broken machinery (elevators, lifts, hoists, etc.)	1.6%
12. Lack of help from another crew member	0.4%
13. Broken tools / small equipment	0.4%
Category 4: Change of Sequence	
14. Someone requested a change of sequence	10.7%
Category 5: Miscommunication	
15. Rework was needed	5.7%
16. Predecessor work not completed	5.7%
Category 6: Other	
17. Other	8.2%
18. Weather impacts	2.0%

Figure 1. The 18 disruptions investigated in the research

planned" – which indicated that improvisation occurred. Disruptions that did not involve any improvisational actions (for example, a worker who stops what they are doing for a few minutes to allow a forklift to pass through their work area but then continues their work exactly as planned) were not reported by the foremen. Hence, time was treated as a control variable and was coded as 1 for all cases of improvisation and thus was not included in the degree of improvisation score.

To develop weights that reflected the relative importance of each plan element to the total improvisation, foremen who participated in the study were posed with a "weighting question." The responses from 42 of the foremen that completed this weighting question (responses from 8 of the 50 foremen could not be obtained) were summed and averaged to create one set of overall weights for each of the four plan elements (Table 1). The result was a weight of 3.97 for a location change, 3.83 for a task change, and 2.19 for a work method change. In order to make the weighting conceptually easier to understand, the weights were standardized by dividing each weight by the work method weight (the lowest average weight), so that the resulting weight for a work method change then became 1.0. This resulted in a relative weight of 1.81 for a location change and 1.75 for a task change 1 (Table 1).

Thus, the index of degree of improvisation ranged from 0.00 if no improvisation occurred (i.e., no deviation occurred from the task, location, or method, or sum of row 1 of Table 2) up to 18.24 if there was a total deviation from the task, location, and method (sum of the last row of Table 2).

Table 1. Weights of plan elements comprising the degree of improvisation scale

Type of Change	Relative Weights
Task Change	1.75
Location Change	1.81
Work Method Change	1.00

Table 2. Index of plan elements comprising the degree of improvisation scale

Responses	Task Scoring	Location Scoring	Work Method Scoring
No deviation	1.75 x 0 = 0.00	1.81 x 0 = 0.00	1.00 x 0 = 0.00
Minor deviation	1.75 x 1 = 1.75	1.81 x 1 = 1.81	1.00 x 1 = 1.00
Moderate deviation	1.75 x 2 = 3.50	1.81 x 2 = 3.62	1.00 x 2 = 2.00
Substantial deviation	1.75 x 3 = 5.25	1.81 x 3 = 5.43	1.00 x 3 = 3.00
Total deviation	1.75 x 4 = 7.00	1.81 x 4 = 7.24	1.00 x 4 = 4.00

Speed of Improvisation was defined as how long it took the foreman to "think through a solution to the disruption" (i.e. how long their improvisation took). The speed was measured on a Likert scale as follows: 1 = less than 1 minute, 2 = between 1 and 5 minutes, 3 = between 6 and 10 minutes, 4 = between 11 and 20 minutes, and 5 as more than 20 minutes.

INVESTIGATING JOBSITE CHARACTERISTICS AND IMPROVISATIONAL DECISION MAKING

Research Question and Hypotheses

The focus of the research reported in this article was to investigate the influence that the project characteristics had on the foremen's ability make fast, improvisational decisions when the work is interrupted -- following one of six types of disruptions. The following two interrelated research questions were investigated:

1. How do the *different types of work flow disruptions* impact the degree and speed of improvisation that occurs by construction foremen?
2. How do the *characteristics of the project's job site* impact the degree and speed of improvisation that occurs following a work flow disruption?

From the research questions, the following testable hypotheses were generated:

Hypotheses 1-5 (H1-H5): The following jobsite characteristics will increase the *degree of improvisation* that occurs after taking into account the influence of the type of plan disruption: (H1) larger crew size; (H2) later stage of the job (versus the earlier or middle stage of the job); (H3) building occupied while under construction (i.e., occupied, versus unoccupied or partially occupied); (H4) greater turbulence / chaos on jobsite; and, (H5) lower time pressure on foremen

Hypotheses 6-10 (H6, H10): The following jobsite characteristics will lengthen the *speed of improvised decision-making* that occurs after taking into account the influence of the type of plan disruption*:* (H6) larger crew size; (H7) later stage of the job (versus the earlier or middle stage of the job); (H8) building occupied while under construction (i.e., occupied, versus unoccupied or partially occupied); (H9) greater turbulence / chaos on jobsite; and, (H10) lower time pressure on foremen.

Hypotheses 11-13 (H11-H13): The following jobsite characteristics will decrease the *degree of improvisation* that occurs after taking into account the influence of the type of plan disruption: (H11) increased level of organization of jobsite; (H12) increased cooperation on jobsite; and, (H13) increased collaboration on jobsite.

Hypotheses 14-16 (H14-H16): The following jobsite characteristics will shorten the *speed of improvisation* that occurs after taking into account the influence of the type of plan disruption: (H11) increased level of organization of jobsite; (H12) increased cooperation on jobsite; and, (H13) increased collaboration on jobsite.

Research Method

Fifty foremen who worked for nine electrical construction companies in the Chicago metropolitan area in the United States were recruited to participate in the study. The authors used an Ecological Momentary Assessment (EMA) method, in which the foremen completed real-time brief momentary assessments of their decisions and actions on a digital device (i.e., a smartphone) following a work flow disruption several times during their workday (Menches and Chen 2013). EMA was selected for use because it captures the thoughts, decisions, and actions of individuals while they are working in their natural job setting. The disruptive event specifically served as the trigger that signaled the foreman to stop what they were doing and fill out a momentary assessment form on the digital device. Consequently, the EMA method increased the possibility of capturing a task disruption and the foreman's step-by-step response to the disruption.

A data collection cycle occurred across two weeks. The cycle involved (1) training the foremen to use the digital devices on Monday morning of Week 1, (2) collecting momentary assessments (i.e., digital surveys) on the smartphone from each foreman for one week, (3) retrieving the devices on Friday afternoon of Week 1 and downloading the data over the weekend, (4) studying the data and creating summaries for the exit interviews, and (5) conducting the exit interviews during Week 2. To launch a data collection cycle, the researcher met with the participating foremen at the jobsite before work started on Monday morning. A package was distributed to each foreman that consisted of a demographic survey and personality assessment. The researcher explained the data collection procedures and demonstrated the operation of the digital device. The foremen completed one trial survey on the device, and then the foremen placed the device in a carrying case, attached the carrying case to their belt, and went to work. Following a disruption, the foremen responded to the digital survey pre-programmed on the device. At the end of the week, the researcher returned to the site to collect the devices. The following week, the researcher conducted exit interviews to discuss the results of the data collection effort with the foremen.

Digital Survey, Demographics, and Personality Assessment

The digital momentary assessment survey consisted of four sections, including (1) questions about being disrupted, (2) improvisational decision-making questions, (3) questions about the severity of the impact of the disruption on productivity, and (4) questions about the effectiveness of the improvised decision. The demographic survey queried foremen about their work experience, training, education, and characteristics of the particular project they were assigned to. Furthermore, each participant completed a 50-item questionnaire designed to assess their unique personality traits.

Summary Statistics for Project Characteristics

The following summary statistics were calculated for the project characteristics:

- The median *crew sizes* was 3 to 4 crew members, and 62% of the responses identified 1 to 4 crew members.
- Of the 47 responses for *stage of job*, only one job was at the "very beginning", 41 where in the middle stages, and five were at the "very end".
- Of the 50 responses for *type of project*, there were 17 hospital projects and 33 non-hospital projects.
- Of the 48 responses for the *occupancy status*, 22 were rated as occupied buildings (46%), seven as partially occupied (15%), and 19 as unoccupied (40%).
- Overall, 51% of the projects were rated as having a medium level of *organization*, with 11% rated as having low or moderately low *organization*, and 38% rated as having moderately high or high *organization*.
- Overall, 49% of the projects were rated as having a medium level of *turbulence*, with 43% rated as having low or moderately low *turbulence*, and 9% rated as having moderately high or high *turbulence*.
- Overall, 47% of the projects were rated as having a medium level of *time pressure*, with 19% rated as having low or moderately low *time pressure*, and 34% rated as having moderately high or high *time pressure*.

- Overall, 45% of the projects were rated as having a medium level of *cooperation*, with 19% rated as having low or moderately low *cooperation*, and 36% rated as having moderately high or high *cooperation*.
- Overall, 47% of the projects were rated as having a medium level of *collaboration*, with 15% rated as having low or moderately low *collaboration*, and 38% rated as having moderately high or high *collaboration*.

Multilevel Data Analysis

For this research, the degree of improvisational decision-making was believed to be a function of the characteristics of the type of disruption that the foreman experienced as well as the characteristics of the project. Furthermore, the individual differences in the foremen were also believed to have a moderating influence on the relationship between disruptions, project characteristics, and improvisational decisions. Consequently, a two-level hierarchical regression model was used to examine the relationships among the variables. The Level 1 model involved evaluating the influence of the type of work flow disruption and project characteristics on the degree and speed of improvised decision-making, while the Level 2 model identified the potential influence of individual foremen traits on the degree and speed of improvisation. Thus, the Level 2 model controlled for the within-person variability in decision-making by each foreman. Consequently, the focus of the analysis was on the Level 1 model that investigated the relationship between the type of disruptions and project characteristics and the degree and speed that the foremen improvised decisions

Furthermore, a varying number of repeated measures (i.e., digital survey responses) were spread unequally over time (i.e., several times per day for several days) and nested within persons, making the data incompatible with the assumptions underlying more traditional statistical methods. Multilevel modeling specifically addressed the hierarchical structure of the data by performing a two-stage analysis that involved a Level 1 model, Level 2 model, and a combined model (Hox 1995).

The dependent variables for the analysis were degree of improvisation and speed of improvisation, investigated in two separate multilevel models: Model A investigated degree of improvisation while Model B investigated speed of improvisation. For both multilevel models, the Level 1 model takes into account the effect of the six different types of disruptions as well as the eight different project characteristics on the degree and speed of improvisation. Hence, the six types of disruptions and eight project characteristics are the Level 1 predictor variables. The Level 2 model takes into account the average fixed effect of each foreman on the degree and speed of improvisation. The two-level structure is demonstrated as follows:

Level 1: $Y_{ij} = \pi_{0j} + \pi_{1j}X_{1ij} + \pi_{2j}X_{2ij} + \pi_{3j}X_{3ij} + \pi_{4j}X_{4ij} + \pi_{5j}X_{5ij} + \pi_{6j}X_{6ij} + \pi_{7j}X_{7ij} + \pi_{8j}X_{8ij} + \pi_{9j}X_{9ij} + \pi_{10j}X_{10ij} + \pi_{11j}X_{11ij} + \pi_{12j}X_{12ij} + \pi_{13j}X_{13ij} + \pi_{14j}X_{14ij} + e_{ij}$

where

- Y_{ij} is a measure of the degree or speed of improvisation by foreman j following disruption i
- X_{1ij}, X_{2ij} … X_{14ij} are the predictor variables (e.g., the six types of disruptions and the eight project characteristics) associated with foreman j following disruption i; for example, X_1 = Type 1 "In the Way" (coded as 0), X_2 = Type 2 "Interrupted By" (coded as 1) … Type 7 "Crew Size" (coded as 6), Type 8 "Stage of Job" (coded as 7) …
- π_{0j} through π_{14j} are the individual regression coefficients associated with a specific foreman j
- e_{ij} is the error, assumed to be normally distributed with mean 0 and variance σ^2

Level 2: $\pi_{0j} = \beta_{00} + r_{0j}$

$\pi_{1j} = \beta_{10}$

$\pi_{2j} = \beta_{20}$

⋮

$\pi_{14j} = \beta_{140...}$where

- π_{0j} through π_{14j} are the individual regression coefficients of foreman j
- β_{00} through β_{140} are the average regression coefficients over all foremen (i.e., fixed effects)
- r_{0j} is the residual error term at the foremen level and can be thought of as unique increments to the fixed effects characteristic of foreman j (i.e., random effects)

In the Level 2 model, each foreman in the study may have a different average degree or speed of improvising (π_{0j}). The combined model (i.e., multilevel regression model) is generated by substituting the π_{0j} through π_{14j} individual (i.e., foreman j) regression coefficients into the Level 1 model.

Results of Hypothesis Testing and Interpretation of Results
Four summary charts (Figures 2, 3, 4, and 5) were created to display the results of the 16 hypothesis tests. The discussion of the hypotheses tests are presented in the next few paragraphs.

The following jobsite characteristics will increase the *degree of improvisation* that occurs after taking into account the influence of the type of plan disruption:			
Hypothesis	**Project Characteristic**	**Statistical Results**	**Effect**
H1	Larger crew size	t = 0.43, p = 0.67	No effect detected
H2	Later stage of job	t = 0.37, p = 0.71	No effect detected
H3	Building occupied	t = -0.42, p = 0.67	No effect detected
H4	Greater turbulence	t = 0.71, p = 0.48	No effect detected
H5	Lower time pressure	t = 1.04, p = 0.30	No effect detected

Figure 2. Results of Hypotheses Testing for H1 through H5

The following jobsite characteristics will lengthen the *speed of improvisation* that occurs after taking into account the influence of the type of plan disruption:			
Hypothesis	**Project Characteristic**	**Statistical Results**	**Effect**
H6	Larger crew size	t = 0.27, p = 0.79	No effect detected
H7	Later stage of job	t = -1.21, p = 0.23	No effect detected
H8	Building occupied	t = -.12, p = 0.90	No effect detected
H9	Greater turbulence	t = 1.79, p = 0.075	Positive effect
H10	Lower time pressure	t = 0.68, p = 0.50	No effect detected

Figure 3. Results of Hypotheses Testing for H6 through H10

The following jobsite characteristics will decrease the *degree of improvisation* that occurs after taking into account the influence of the type of plan disruption:			
Hypothesis	**Project Characteristic**	**Statistical Results**	**Effect**
H11	Increased organization	t = -2.01, p = 0.05	Negative effect detected
H12	Increased cooperation	t = -1.55, p = 0.12	Negative effect detected
H13	Increased collaboration	t = 2.02, p = 0.05	Positive effect detected

Figure 4. Results of Hypotheses Testing for H11 through H13

The following jobsite characteristics will shorten the *speed of improvisation* that occurs after taking into account the influence of the type of plan disruption:			
Hypothesis	**Project Characteristic**	**Statistical Results**	**Effect**
H14	Increased organization	t = -0.52, p = 0.61	No effect detected
H15	Increased cooperation	t = 1.95, p = 0.05	Positive effect detected
H16	Increased collaboration	t = -1.70, p = 0.09	Negative effect detected

Figure 5. Results of Hypotheses Testing for H14 through H16

Interpretation of H1 and H6 Testing for Larger Crew Size Effect: Because it seemed logical that supervising more crew members would require more decision-making by the foremen, it was hypothesized that supervising more crew members would lead to greater degrees of improvisation and a longer speed of improvisation. However, the findings did not support these hypotheses. A larger crew size did not increase the degree of improvisation ($t = 0.43$, $p = 0.67$) or the speed of improvisation ($t = 0.27$, $p = 0.79$). One possible explanation for this finding is that most of the improvised decisions, in general, were relatively minor (48%) or moderate (23%) and could be generated quickly (i.e., in less than five minutes) (77.5%). Thus, supervising a greater number of crew members simply resulted in a greater number of minor improvised decisions that could be generated rapidly rather than resulting in more extensive improvised decisions that took longer to generate.

Interpretation of H2 and H7 Testing for Later Stage of Job Effect: Performing work during a later stage of the job was theorized to increase the degree of improvisation. In the early stage, the work is just getting started and there are fewer obstacles to performing the work. The middle stage of projects is typically called the "wide open" stage where there is frequently an abundance of tasks for crew members to work on, and crew members can quickly be re-assigned if their task is interrupted. The later stage of a project is driven by the punch list, which is a list of all the miscellaneous or incidental items that must be repaired or completed prior to the job ending. The punch list can often be tedious to complete and the items on it may be geographically dispersed and diverse, requiring different tools and methods to complete each item. Punch list items may also require specific materials or parts. For these reasons, it was theorized that the very end stage of the project would require a greater degree of improvisation and a longer speed of improvisation than the early or middle stages.

The analyses comparing the stage of the job to both the degree and speed of improvisation determined that the relationships were not statistically significant ($t = 0.37$, $p = 0.71$ and $t = -1.21$, $p = 0.23$, respectively). One possible explanation for this finding is that much of the data was collected during the middle stage of jobs, with few disruptions recorded during the very beginning stage or the very end stage. Unfortunately, the authors could not control the timing of the job stage because companies volunteered the projects, and few jobs in the early and late stages were volunteered by companies. Perhaps a future study could actively seek jobs at the very beginning and very end stages to readdress these hypotheses.

Interpretation of H3 and H8 Testing for Occupancy Status of Job Effect: It was hypothesized that occupied worksites would generate greater degrees of improvisation and also a longer speed of improvisation than partially occupied worksites, and that partially occupied worksites would generate greater degrees of improvisation and also a longer speed of improvisation than unoccupied worksites. However, there was no statistically significant difference in either the degree ($t = -0.42$, $p = 0.67$) or speed ($t = -0.12$, $p = 0.90$) of improvisation across these three occupancy scenarios. This finding made the authors theorize further about the characteristics of an occupied building might make it generate more or less extensive improvisational decisions at a faster or slower speed. These factors might include the congestion of occupants in an area, diminished accessibility of an area due to occupants, and noise or dust restrictions. Furthermore, in an occupied building, a foreman might have occupants in the way, the occupants might restrict movement of crews, and accessibility may be limited. However, similar conditions may exist in unoccupied buildings if the site becomes congested by excess trader workers as opposed to occupants. Consequently, similar conditions may exist in both occupied and unoccupied buildings. Further research would have to isolate these individual variables within the occupancy level of a building to test this theory.

Interpretation of H4 and H9 Testing for Turbulence Effect: Turbulence or chaos is theorized to be the result of congested job sites, a rushed work environment, and perhaps unorganized or otherwise apathetic jobsite management either from the general contractor superintendent or project manager. Turbulence is thus theorized to increase the degree of improvisation and to lengthen the speed of improvisation. It was found that jobsite turbulence did not have a statistically significant effect on the degree of improvisation ($t = 0.71$, $p = 0.48$), but was statistically significant in lengthening the speed of improvisation (at the $p = 0.10$ level) ($t = 1.79$, $p = 0.075$). One possible explanation for this result is that the foreman must mentally process a significant amount of information when the jobsite is turbulent, and as a result, the generation of a new course of action may take additional time. For example, it might not be immediately possible whether a crew member can be assigned to a different location because the new location may be unexpectedly occupied by other trades or may be cluttered with materials or debris. Hence, it will conceivably take the foreman longer to generate new plans that can, in fact, be executed.

Interpretation of H5 and H10 Testing for Time Pressure Effect: It was hypothesized that lower amounts of time pressure experienced by the foreman when re-planning would increase the degree of improvisation and lengthen the speed of improvisation. The analysis did not statistically support these hypotheses (t = 1.04, p = 0.30 and t = 0.68, p = 0.50 respectively). Other research has suggested that foremen frequently feel time pressure, and as a result, they have developed coping mechanisms that allow them to deflect the negative impacts of time pressure (Hinze 1981; Menches and Saxena 2013). Consequently, their performance under high and low time pressure may not differ significantly. Furthermore, given that minor and moderate improvisational decisions were more common (71%), and faster decision were more common (77.5%), it may have been difficult to see a pattern in the current data set. Although it seems intuitively logical that, when experiencing less time pressure, foreman may be more likely to develop more extensive improvised decisions and may take more time to generate these choices, additional targeted research is needed to determine whether time pressure does, in fact, have an impact on the development of improvised decisions.

Interpretation of H6 and H11 Testing for Jobsite Organization Effect: The hypothesis was that greater jobsite organization and structure would decrease the degree of improvisation and would shorten the speed of improvisation (i.e., result in faster decision-making). A statistically significant relationship between jobsite organization and the degree of improvisation was identified after controlling for the type of disruption (t = -2.01, p = 0.05), indicating that greater jobsite organization was related to a decrease in the degree of improvisation deployed in response to disruptions. However, no statistically significant relationship was found between the jobsite organization and the speed of improvisation (t = -0.52, p = 0.61). This was a surprise since greater organization was believed to make the decision-making process faster. This result might be worth examining in further detail in future research.

Interpretation of H12, H13, H15, and H16 Testing for Cooperation and Collaboration Effects: H12, H13, H15, and H16 suggest that higher levels of cooperation and higher levels of collaboration will result in a decrease in the degree of improvisation and will shorten the speed of improvisation (i.e., the decision-making is faster).

A modest relationship was detected between the level of cooperation and degree of improvisation, and this relationship was negative but did not quite rise to the level of statistical significance (t = -1.55, p = 0.12), indicating that increased levels of cooperation are moderately more likely to result in less extensive improvisation. Furthermore, a statistically significant relationship was detected between the level of cooperation and the speed of improvisation (t = 1.95, p = 0.05), but the relationship was positive, indicating that greater levels of cooperation tend to lengthen the speed of improvisation (i.e. the decision-making process takes longer).

A statistically significant relationship was detected between the level of collaboration and the degree of improvisation, but the relationship was positive (t = 2.02, p = 0.05), indicating that a higher level of collaboration resulted in more extensive improvisation. Furthermore, a statistically significant relationship was detected between the level of collaboration and the speed of improvisation (t = -1.70, p = 0.09), but the relationship was negative, indicating that greater levels of collaboration tend to shorten the speed of improvisation (i.e. the decision-making process is shorter).

Recall that cooperation can be defined as listening to other's ideas and also working to help one another, while collaboration can be defined as parties voluntarily engaged in shared decision-making as they work towards a common goal. Perhaps another distinction is the formality of the two, with cooperation typically taking on an informal arrangement (e.g., it often happens spontaneously when the immediate need arises), while collaboration is a more structured arrangement (e.g., it often involves greater levels of communication and planning). While cooperation and collaboration are often treated interchangeably, the two concepts are different, and the foremen (i.e., respondents) demonstrated an understanding of the difference between cooperation and collaboration as evidence by the fact that, of the 47 total responses from the 50 foremen, approximately 1/3 of the cases (15/47) had the cooperation level of the project rated differently on the 5-point Likert scale than the collaboration level on the same project.

Assuming that cooperating is viewed as a tool so that each party can accomplish their own goals, but collaboration is viewed as a method of actually working together for common goals, the results are understandable. On jobsites where there is greater cooperation, the degree of improvisation deployed will be less because other trades will be more willing to accommodate changes to the work, thus requiring less extreme actions as a result of a disruption. The results also indicate that improvisational decisions and actions will be slower on cooperating sites, and one possible explanation for this finding is that foremen may want to make sure their improvised actions do not adversely impact the other cooperating trades on the job site, and thus the decisions are made more slowly.

Finally, the results indicated that increased collaboration will lead to more extensive improvisational decisions, but the decisions are made faster. One possible explanation for the findings is that collaboration may be occurring to a greater extent during the planning process and involves joint decision-making. Given that more of the trades are involved in making single decisions on a collaborative site, the process of improvising a decision may lead to more complex improvised decisions that benefit multiple parties rather than just the trade that experiences the immediate disruption. At the same time, the improvised decision may take less time to generate because the parties may have prepared contingency plans for potential interruptions and may simply need to agree to deploy the new plan of action. Additional research is needed to determine whether the theorized explanation is true.

SUMMARY AND FUTURE RESEARCH DIRECTION

This article examined the relationship between specific construction jobsite characteristics and the degree and speed of the improvised decisions of the foremen deployed as a result of the interaction between the characteristics and workflow disruptions. Existing research suggests that improvisation can assist in improving the work flow on jobsites and can fill gaps in planning, but not much is known about which jobsite characteristics may generate greater or lesser degrees of improvisation or greater or lesser speeds of improvisation. The findings indicate that on construction projects that are rated by the foremen as more organized and more cooperative, the foremen can make more modest improvised decisions to resolve a disruption, but on construction projects that were rated by the foremen as more collaborative, a greater degree of improvisation was deployed in response to a disruption. In addition, it was found that on sites that were rated by the foremen as more cooperative, the foremen required more time to improvise their decisions. Additional research is needed to unpack the elements of organized, cooperative, or collaborative jobsites that influence the improvisation on the jobsites.

Practically, the findings suggest that a more organized jobsite that has a more cooperative team of contractors may be desirable because it requires less extensive improvisational decisions and actions resulting from more minor (rather than major) disruptions that can be resolved with minimal actions. And, while a collaborative team is also desirable, the joint decision-making that is a hallmark of collaboration may generate more extensive improvisational decisions and actions because more parties are involved in the improvisation process, but these more sophisticated improvisational decisions and actions may be implemented more rapidly because of the spirit of teamwork on the jobsite.

ACKNOWLEDGMENTS

This research was funded by The National Science Foundation under grant number CMMI-1100514. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation

REFERENCES

Asher, M. F., Tolhurst, D. J., Troscianko, T., & Gilchrist, I. D. (2013). "Regional effects of clutter on human target detection performance." Journal Of Vision, 13(5)

The Associated General Contractors of America (AGC). (2006). “The contractors’ guide to BIM.” www.agcnebuilders.com/documents/BIMGuide.pdf Jul. 2, 2009

Australian Department of Treasury and Finance (ADTF2006). “Project alliancing practitioners’ guide.” http://www.dtf.vic.gov.au/CA25713E0002EF43/WebObj/CompleteProjectAllianceGuide/$File/Complete%20Project%20Alliance%20Guide.pdf Jul. 2, 2009

Brown, S. L., and Eisenhardt, K. M. (2002). "The art of continuous change: Linking complexity theory and time-paced evolution in relentlessly shifting organizations." Organizational improvisation, K. K. Kamoche, M. P. e. Cunha, and J. V. d. Cunha, eds., Routledge, New York, 229-261.

Campion, M. A., Medsker, G. J., & Higgs, C. A. (1993). "Relations between work group characteristics and effectiveness: Implications for designing effective work groups." *Personnel Psychology*, 46, 823–831.

Chatman, J., Polzer, J., Barsade, S., & Neale, M. (1998). "Being different yet feeling similar: The influence of demographic composition and organizational culture on work processes and outcomes." *Administrative Science Quarterly*, 43, 749–780.

Ciborra, C. U. (1999). "Notes on improvisation and time in organizations." *Accounting, Management, and Information Technologies*, 9(2), 77-94.

Eastman, C., Teicholz, P., Sacks, R., and Liston, K. (2008). "BIM hand-book: A guide to building information modeling for owners, managers, designers, engineers, and contractors", Wiley, Hoboken, N.J.

Friend, M. & Cook, L. (2000). Interactions: Collaboration skills for school professionals. New York: Longman.

Hinze, J. (1981). "Productive foreman characteristics." *Journal of the Construction Division*, 107(CO4), 627-639.

Hox, J. J. (1995). *Applied multilevel analysis*, TT-Publikaties, Amsterdam, The Netherlands.

Kent, D. C., & Becerik-Gerber, B. (2010). "Understanding Construction Industry Experience and Attitudes toward Integrated Project Delivery". *Journal Of Construction Engineering & Management*, *136*(8), 815-825. doi:10.1061/(ASCE)CO.1943-7862.0000188

Kennedy S, Stewart H. "Collaboration between occupational therapists and teachers: Definitions, implementation and efficacy." *Australian Occupational Therapy Journal* [serial online]. June 2011;58(3):209-214. Available from: PsycINFO, Ipswich, MA. Accessed August 29, 2013.

King, E. B., Hebl, M. R., & Beal, D. J. (2009). "Conflict and cooperation in diverse workgroups". *Journal Of Social Issues*, *65*(2), 261-285. doi:10.1111/j.1540-4560.2009.01600.x

Kirsh, D. (2000). "A Few Thoughts on Cognitive Overload." *Intellectica*, *30*19-51.

Leybourne, S. (2010). "Project management and high-value superyacht projects: An improvisational and temporal perspective." *Project Management Journal*, 41(1), 17-27.

Luke, D. A. (2004). "Multilevel modeling." Quantitative applications in the social sciences, M. S. Lewis-Beck, ed., Sage Publications, Inc., Thousand Oaks, CA, 79.

Menches, C. L., and Chen, J. (2013). "Using ecological momentary assessments to understand a construction worker's daily disruptions and decisions." *Construction Management and Economics*, 31(2), 180-194.

Menches, C. L., and Saxena, J. (2013). "Understanding construction workers' risk decisions using Cognitive Continuum Theory." Working Paper No. 3056, Illinois Institute of Technology, Chicago, IL.

Mendonça, D., and Wallace, W. A. (2002). "Development of a Decision Logic to Support Group Improvisation: An Application to Emergency Response." Hawaii International Conference on System Sciences (HICSS-35), Big Island, HI.

Milton, L. P., & Westphal, J. D. (2005). "Confirmation networks and cooperation in workgroups." *Academy of Management Journal*, 48, 191–212.

Miner, A. S., Bassoff, P., and Moorman, C. (2001). "Organizational improvisation and learning: A field study." *Administrative Science Quarterly*, 46(2), 304-337.

Noble, C.(2007). "Can project alliancing agreements change the way we build?". *Architectural record* http://archrecord.construction.com/practice/projDelivery/0707proj-1.asp Jul. 2, 2009

Pelled, L., Eisenhardt, K., & Xin, K. (1999). "Exploring the black box: An analysis of work group diversity, conflict, and performance." *Administrative Science Quarterly*, 44, 1–28.

Williamson, A. (1998). "Moneypenny: Lessons from the messy desk." *Interacting With Computers*, *9*(3), 241-267. doi:10.1016/S0953-5438(97)000