Exploring the role of team environment in building project performance

Bryan FRANZ\textsuperscript{1}, Behzad ESMAEILI\textsuperscript{2}, Robert LEICHT\textsuperscript{3}, Keith MOLENAAR\textsuperscript{4} and John MESSNER\textsuperscript{5}

\textsuperscript{1}Graduate Research Assistant, Department of Architectural Engineering, The Pennsylvania State University, 104 Engineering Unit A, University Park, PA 16801; email: bwf114@psu.edu

\textsuperscript{2}Assistant Professor, Durham School of Architectural Engineering and Construction, University of Nebraska-Lincoln, 113 Nebraska Hall, Lincoln, NE 68588; email: besmaeili2@unl.com

\textsuperscript{3}Assistant Professor, Department of Architectural Engineering, The Pennsylvania State University, 104 Engineering Unit A, University Park, PA 16801; email: rmleicht@engr.psu.edu

\textsuperscript{4}Professor, Department of Civil, Environmental and Architectural Engineering, University of Colorado Boulder, Campus Box 428, Boulder, CO 80309; email: molenaar@colorado.edu

\textsuperscript{5}Professor, Department of Architectural Engineering, The Pennsylvania State University, 104 Engineering Unit A, University Park, PA 16801; email: jmessner@engr.psu.edu

ABSTRACT

Design and construction projects incorporate stakeholders from many different organizations, often with conflicting goals, overlapping responsibilities and differing areas of expertise. With an increasing interest in improving the ‘integration’ and collaboration on construction projects, there is a need for empirical research to understand the contributions of project team interactions to project-level performance. The purpose of this paper is to explore the correlations between several indicators of the collaborative team environment and traditional measures of project success. With the assistance of an industry advisory board, a survey questionnaire was developed to collect detailed information for recently completed building projects in the United States. The questionnaire was distributed via mailing lists, conferences and industry contacts to reach a diverse set of respondents. Using this large data set of 124 projects, bivariate Spearman rho correlation coefficients are calculated and reported. Significant correlations suggest the role of on-time communication in reducing construction cost growth, higher team chemistry in reducing overall schedule growth and larger administrative burdens in increasing construction cost growth and final unit cost. Multicollinearity among the measures of team environment suggests the presence of latent variables and need for future multivariate analyses.
INTRODUCTION

As building projects have become more complex, the construction industry has trended towards a greater specialization of design consultants and trade contractors. The ideal of the ‘master builder’ has been fragmented into an array of separate disciplines and fields of expertise. Project execution now requires the participation of multiple organizations—the steel frame for a building may be designed by a structural engineer, machined and delivered by a steel fabricator, installed by a steel subcontractor and coordinated by a construction manager. Contracts and delivery methods often reinforce this separation, leading to siloed behavior and the defining of success in terms of individual stakeholder metrics instead of overall project outcomes (Cornick and Mather 1999). Additionally, fragmentation in the team selection process, resulting from the separate management of design and construction activities, frequently leads to the development of adversarial relationships, lack of trust and poor transparency (Latham 1994, Egan 1998, Berggren et al. 2001). When considered alongside other trends in the architecture, engineering and construction (AEC) industry, including the reduction in time to market expectations from owners and an increase in building system interconnectivity, the team environment in modern construction projects are becoming a central focus in improving project performance.

As part of a larger, ongoing study on the antecedents of project success, this paper presents a narrower discussion of correlations, specifically between measures of the team environment and project performance. Design and construction projects incorporate team members from many different organizations, often with conflicting goals, overlapping responsibilities and differing areas of expertise. Each stakeholder balances the need for maintaining independence and facilitating activities within their own organization, with the need to act interdependently and exchange information to procure resources with other members of the project team (Drach-Zahavy and Somech 2010). These relationships are frequently temporary, existing for a limited time and working towards a pre-established goal, before dissolving upon completion of the contracted scope. Collaborative working practices are frequently discussed in literature and considered to have a positive impact on the delivery of building construction projects. Aggregating from multiple sources, Greenwood and Wu (2012) define collaboration between parties as “working together for mutual advantage, through which they can achieve greater benefits than by working separately”. Although broad, this description of collaboration in team environments is closely related to discussions on cooperation in partnerships (Bresnen and Marshall 2002) and project team integration (Baiden, Price and Dainty 2006). With this increasing interest in improving the ‘integration’ and collaboration on construction projects, there is a need for empirical research to study the impact of team environments on project performance. Prior AEC research has addressed this topic with small sample analyses or case studies, which lack the strong quantitative support needed to inform change in the industry. Using data collected via questionnaire from 124 recently completed building projects, this paper explores the effectiveness of several indicators of a collaborative team environment in influencing project success.
POINT OF DEPARTURE

Industry interest in creating more effective project teams is expanding, targeting the structural elements with relational contracting strategies, such as integrated project delivery (IPD), and knowledge exchanges using information technology, such as building information modeling (BIM). Driving this interest is the desire to improve the effectiveness of collaborative team environments, which is frequently correlated with team performance in social science research and starting to show similar results in AEC applications (Greenwood and Wu 2012). Prior studies suggested that delivery methods, specifically those enabling early builder involvement and more integrated design and construction teams, are positively correlated with project cost, schedule and sustainability outcomes (Konchar and Sanvido 1998, Ibbs et al 2003, Bogus et al. 2010, Korkmaz, Riley and Horman 2010). However, these studies were limited in their approach to measuring or comparing integration and therefore can only speculate on how the team environment may have improved or hindered the collaboration achieved between project team members.

In inter-organizational literature, the degree of collaboration or levels of ‘working together’ are often viewed as a continuum. Peterson (1991) suggested three stages, beginning with cooperation, moving to coordination and ending with collaboration. Konrad (1996) expanded the scale by proposing five levels, including information sharing, cooperation and coordination, collaboration, consolidation and integration. Lastly, Bailey and Konley (2000) posited a related five levels, ranging from cooperation, coordination, coalition, collaboration and integration. Empirical research in the AEC industry along these continuums is limited, although two recent studies look specifically at the role of cooperation and collaboration in project performance. Studying the Hong Kong construction industry, Phua and Rowlinson (2004) found that cooperation and contractual characteristics were predictors of project success, and with varying levels of importance between contractor and consultant firms. An important contribution of this study was the identification of indicators for cooperation on projects to allow for more detailed analyses. Greenwood and Wu (2012) performed a similar study, but considered the collaborative environment by collecting data on both positive and negative attributes of collaborative working. Their analysis demonstrated a clear association between collaboration and the control of cost and schedule, the quality of work and user satisfaction on building projects. Along the same line of inquiry, the correlations presented in this paper relate an industry-generated list of team environment variables with commonly cited measures of project-level performance.

METHODOLOGY

As part of the larger, ongoing study, this research created a survey questionnaire to collect completed project data from project participants. The questionnaire topics were developed using a combination of prior project delivery method studies (Konchar and Sanvido 1998, Molenaar et al. 1999, El Wardani et al. 2006, Korkmaz et al. 2010) and the results of a two-day industry workshop, attended by a diverse group of owners, contractors and designers. Each workshop attendee had at least ten years of working experience in the construction industry and served as
an active member in at least one large professional organization. These industry members were not intended to represent the voice of an entire industry, but rather as a group interested in understanding and improving the project delivery process. Summarized by Esmaeili et al. (2013), the workshop identified several processes, technologies and team behaviors perceived to influence project performance. The resulting questionnaire requested both detailed quantitative data (e.g. contract values and schedule dates) and qualitative assessments of the team environment. The questionnaire was distributed via mailing lists for professional organizations with diverse memberships, such as the Design-Build Institute of America (DBIA) and Construction Owners Association of America (COAA), as well as industry contacts through Penn State University and the University of Colorado Boulder. The questionnaire was intended primarily for owners, as owners have the most complete knowledge of the project; however contractors, construction managers and designers are not discouraged from participating.

**Assessing Project Performance**

Consistent with prior project delivery literature, the project-level performance measures considered in this paper include construction cost growth, overall schedule growth and final unit cost. A summary of these variables and their associated calculation methods is provided in Table 1. Each questionnaire response receives a follow-up contact from the research team to validate several key data points, including contract values, schedule dates and gross building area. This validation step is necessary to ensure consistency across the project data. For example, the construction costs do not include property costs, furnishings or costs of installed process or manufacturing equipment. Although the questionnaire also collected performance data related to quality, safety and sustainability, these outcomes were omitted from this stage of the correlation analysis.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Equation</th>
</tr>
</thead>
</table>
| Construction cost growth (%) | \[
|                             | \frac{(Final\ construction\ cost - Initial\ construction\ cost)}{Initial\ construction\ cost} \times 100 \] |
| Overall schedule growth (%)   | \[
|                             | \frac{(Actual\ duration - Planned\ duration)}{Planned\ duration} \times 100 \] |
| Final unit cost ($/ft^2)      | Final project cost / Gross area                                          |

**Measuring the Team Environment**

The survey questionnaire used a visual analogue scale (VAS) to measure characteristics of the project team environment. These characteristics were selected from the key predictors of project success identified by Esmaeili et al. (2013), which were collected and rated from a diverse group of industry professionals. As shown in Table 2, the scales were represented by equidistant circles anchored with appropriate terminal labels for each variable. Commonly used in psychology and medical fields, visual analogue scales are used to measure the frequency or intensity of subjective characteristics that cannot be directly measured (Hayes and Patterson 1921).
Considered similar to Likert scales, a VAS may be represented either by a continuous horizontal line or equally spaced discrete response categories. However, unlike a Likert scale, a VAS does not explicitly describe or label each response category, opting instead to only define the end points as the extreme limits of the variable being studied, allowing the scale to appear continuous from the respondent’s perspective.

### Table 2: Team environment variables and associated visual analogue scales

<table>
<thead>
<tr>
<th>Variables</th>
<th>Visual Analogue Scale (VAS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Administrative burden</td>
<td>Low: 0 0 0 0 0 0 High: 0 0 0 0 0 0</td>
</tr>
<tr>
<td>Staff turnover</td>
<td>Low: 0 0 0 0 0 0 High: 0 0 0 0 0 0</td>
</tr>
<tr>
<td>Prior experience as unit</td>
<td>Low: 0 0 0 0 0 0 High: 0 0 0 0 0 0</td>
</tr>
<tr>
<td>Team chemistry</td>
<td>Poor: 0 0 0 0 0 0 Excellent: 0 0 0 0 0 0</td>
</tr>
<tr>
<td>Compromise, frequency</td>
<td>Never: 0 0 0 0 0 0 Frequently: 0 0 0 0 0 0</td>
</tr>
<tr>
<td>Communication, timeliness</td>
<td>Never on time: 0 0 0 0 0 0 Always on time: 0 0 0 0 0 0</td>
</tr>
<tr>
<td>Communication, formality</td>
<td>Informal: 0 0 0 0 0 0 Formal: 0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

### Correlation Methods

Since VAS responses are subjective and not directly comparable across groups of individuals, statistical techniques based on the rank ordering of scores, rather than the arithmetic means, are more appropriate for analyzing team environment data. Therefore, the correlational results presented in this paper were calculated as nonparametric, Spearman rho coefficients. The VAS response categories for each team environment variable were coded as a discrete ordinal scale, using integers from 1 at the left end point, and increasing to 6 at the right end point. Since nonparametric tests make no assumptions on the distribution of the sample, no transformations were needed to normalize the data.

### RESULTS

Collected over a period of four months, the preliminary results presented in this paper are a work-in-progress, providing an exploratory perspective on the role of the team environment in achieving project success. Additional data from questionnaires and non-response contacts are still being accepted and validated by the research team, which will enable future research examining this data in greater detail. Sample demographics are presented to contextualize the correlational results by describing the types of projects we have received to-date through questionnaire responses.

### Sample Data Demographics

The projects included in the correlational analysis were distributed across several building types. Comprising nearly 40% of the sample, offices and educational projects are the highest represented building types, followed by health care and industrial projects. The size distribution of projects included in the study, in square-feet, is provided in Figure 1. There are nearly equal percentages of small, small-medium and medium-large projects, and fewer large projects. A comparison of
the sector owning the projects is also included, which is slightly skewed toward public owners at 60% of the representation across each size grouping.

![Building Size (ft²)](chart)

**Figure 1:** Sample distribution for building size

In addition to project size demographics, the sample distribution of the organizational elements is also relevant in understanding the context of correlational results. Specifically, Figure 2 shows the distribution of project delivery methods. Design-build was the most common, used in over 40% of projects in the data set, followed by 35% with construction manager (CM) at risk and 20% with design-bid-build (DBB). Only a small number of projects, roughly 4%, were confirmed to have used a formal multiparty agreement for integrated project delivery (IPD). A similar skew is observable in Figure 3, where the dominant form of builder selection is a request for proposal (RFP) in over 50% of the projects. Prequalified bid and sole source have roughly equal representation of near 20% each, and low bid as the least common selection process at less than 10%. Lastly, Figure 4 identifies lump sum as the builder payment terms with the highest frequency of occurrence in the sample data set. Guaranteed maximum price (GMP) was also highly represented, with cost plus a fixed or percent fee being reported less frequently.
Figure 2: Sample distribution for project delivery method

Figure 3: Sample distribution for builder selection process
Correlational Analysis

Recognizing the limitations of a work-in-progress data set and the exploratory nature of the topic area, numerical correlation values are not presented in this paper. Instead, letters denoting the size, direction and significance of the correlations are shown in Table 3. Each letter corresponds to a range of values, intended to document the relative effect size or strength of the correlation: Small (S) for correlations between -0.10 and -0.29 or 0.10 and 0.29; Medium (M) between -0.30 and -0.49 or 0.30 and 0.49; Large (L) between -0.50 and -1.0 or 0.50 to 1.0 (Cohen 1988). Very small correlations between -0.1 and 0.1 were intentionally omitted from Table 3, regardless of significance level. The sample size of each correlation ranged from 69 to 124 projects, depending on the completeness of pairwise response data.
Of the seven measures of team environment, three were significantly correlated with project performance: Communication timeliness had a small, negative relationship with construction cost growth; team chemistry a medium, negative relationship with schedule growth; and administrative burden a small, positive relationship with both construction cost growth and final unit cost. Several significant correlations were also observed among the team environment variables when paired together, specifically between team chemistry and communication timeliness.

### Table 3: Spearman rho correlation size between project environment and performance measures

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Construction cost growth</td>
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<td>2. Schedule growth</td>
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<td>3. Unit cost</td>
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<tr>
<td>4. Administrative burden</td>
<td>S**</td>
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<td>S**</td>
<td>1</td>
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<tr>
<td>5. Staff turnover</td>
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<td>--</td>
<td>--</td>
<td>S*</td>
<td></td>
<td></td>
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<tr>
<td>6. Prior experience as unit</td>
<td>-S</td>
<td>--</td>
<td>-S</td>
<td>-S</td>
<td></td>
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</tr>
<tr>
<td>7. Team chemistry</td>
<td>-S</td>
<td>-M**</td>
<td>--</td>
<td>-S*</td>
<td>-M***</td>
<td>S**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Compromise, frequency</td>
<td>-S</td>
<td>--</td>
<td>-S</td>
<td>-S</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>S*</td>
<td></td>
</tr>
<tr>
<td>9. Communication, timeliness</td>
<td>-S**</td>
<td>-S</td>
<td>-S</td>
<td>-S*</td>
<td>-M***</td>
<td>-S*</td>
<td>L***</td>
<td>S*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Communication, formality</td>
<td>S</td>
<td>-S</td>
<td>--</td>
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<td>--</td>
<td>--</td>
<td>-S*</td>
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<td>1</td>
</tr>
</tbody>
</table>

**Notes:** Letters denote correlation size: S = Small, M = Medium, L = Large; *p < 0.05; **p < 0.01; ***p < 0.001
DISCUSSION

A collaborative environment is not directly procured by project owners when assembling the design and construction team. Yet many architects, contractors and consultants are intuitively aware of differences between collaborative and adversarial working environments, and their perceived impact on project performance. The bivariate correlation results presented in this paper confirm these perceptions, highlighting the importance of multiple measures of the team environment in achieving building project success:

- Higher ratings of *timely communication*, indicating that information was more often ‘always on time’, were weakly correlated with reduced construction cost growth.

- Higher ratings of *team chemistry*, indicating ‘excellent’ functionality as a team, were moderately correlated with reduced overall schedule growth.

- Higher ratings of *administrative burden*, indicating a ‘high’ amount of paperwork and bureaucracy, were weakly correlated with increases in construction cost growth and final unit cost of the project.

Beyond their impact on project performance, measures of the team environment showed a high degree of multicollinearity, which suggests the presence of latent variables. A principal component analysis (PCA) was not performed for this paper, but examination of the correlation matrix reveals several variables that ‘move together’, with correlations of similar size and direction. As shown in Table 4, a truncated version of the full correlation matrix, *team chemistry* and *timely communication* have a strong positive relationship with each other. Additionally, both variables are negatively correlated with increases in *administrative burden* and *staff turnover*. In other words, on-time communication increases with perceived team chemistry (and vice versa), and decreases under both heavy administrative burden and frequent staff changes. These four variables (administrative burden, staff turnover, team chemistry and timely communication) are interrelated, but what is the underlying factor driving their correlations?

Table 4: Spearman rho correlation size between team environment variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Administrative burden</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Staff turnover</td>
<td></td>
<td>S*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Prior experience as unit</td>
<td></td>
<td>-S</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Team chemistry</td>
<td></td>
<td>-S*</td>
<td>-M***</td>
<td>S**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Compromise, frequency</td>
<td></td>
<td>-S</td>
<td></td>
<td>S</td>
<td>S*</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9. Communication, timeliness</td>
<td></td>
<td>-S*</td>
<td>-M***</td>
<td>-S*</td>
<td>L***</td>
<td>S*</td>
<td>1</td>
</tr>
<tr>
<td>10. Communication, formality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Notes: Letters denote correlation size: S = Small, M = Medium, L = Large; *p < 0.05;
One potential factor may be the hierarchy or organization of the project team. For example, *team chemistry* and *timely communication* are inherently aggregate measures, representing perceptions formed from the respondent’s day-to-day interactions on the project. The basis of these perceptions may derive from the frequency, medium and quality of information exchanges, the duration of relationships, and the compatibility with personalities of individual team members. Prior studies on cross-functional teams show similar correlational relationships to those presented in Table 4, although the specific terminology varies in literature. In product development teams, Ancona and Caldwell (1992) found a significant positive correlation between team cohesiveness and the frequency of communication. The organization of the team may also be a factor in the measured *administrative burden* and *staff turnover*, which are indicative of cumbersome interactions or having the ‘wrong’ individual in a given role. In consulting teams, Marrone et al. (2007) found a negative correlation between ‘role overload’ (the perception that a team member has taken on too much work) and team performance. Many of these interactions are guided by the structure of the team, as lines of communication drawn by the delivery method and contractual allocation of roles and responsibilities.

An alternate factor may be the intensity of the project. Larger engineering projects, with fast-tracked schedules and complex building systems, require more management in less time (Miller and Lessard 2000). As demonstrated by Ling et al. (2004), a low reported administrative burden reported was influenced by the contractor’s past performance on similar projects and a high level of staffing. Both of these influences represent awareness to the importance of managing organizational complexity. Heavy administrative burdens may strain the project team, leading to ‘burnout’, difficulties retaining key team members, and ultimately more frequent *staff turnover*. Therefore, within high intensity team environments, it would be reasonable for the respondent’s perception of *team chemistry* and *timeliness of communication* to decrease in response.

**CONCLUSIONS**

The aim of this research was to explore relationships between measures of the team environment and building project outcomes. Significant correlations were found with cost and schedule metrics, suggesting that elements of collaboration have a role in achieving project success. The presence of multicollinearity among a group of team environment variables demonstrated the need for multivariate techniques in future work, such as factor analysis or structural equation modeling (SEM), to pinpoint the underlying driver of team behavior. Yet, the correlations discussed here inspire more practical questions for project teams looking to improve their performance: *What technologies or processes can improve the timeliness of communication among team members?* *How does an owner select a designer and contractor with the best team chemistry?* *What delivery method produces the lowest administrative burden for the project team?* The correlations documented in this paper were calculated across the current sample of 124 building projects, and are representative of the U.S. building construction industry. However, due to small sub-
sample sizes, the correlations could not be performed and reported for a specific building type or sector. As a goal of future research tasks, and dependent on the continuing effort to increase our project sample size, these relationships will be verified for public and private owners, as well as different types of buildings and delivery methods.

Although this paper presents robust correlational results, there are limitations to address in future work. Most notably, this research relies on the respondent’s subjective perceptions of the team environment and the time lag between project completion and the administration of the survey questionnaire could introduce hindsight bias. For example, a very successful project may lead respondents to overlook deficiencies in team interactions. This after-the-fact reasoning could incorrectly conclude that if the project was successful, then the team chemistry must have been excellent, and vice versa. The generalizability of these research findings will depend on the degree by which self-selection of projects by respondents receiving the questionnaire biases the sample. Self-selection bias may occur if respondents demonstrate a preference for completing the questionnaire for a specific type of project, such as sharing only ‘good’ or favorable project experiences. Two steps were taken to reduce this type of response bias. First, the instructions distributed with the questionnaire explicitly requested a wide ‘array of projects, both typical and challenging’ to inform respondents that the study is not targeting a specific type of project or outcome. Secondly, respondents were asked to rate the overall success of the project. The distribution of the ratings from this question will be used in future work to identify the skew of any self-selection bias in the data.

ACKNOWLEDGEMENTS

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