



CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

**Communication, Trust & Performance:
The Influence of Trust on Performance
in A/E/C Cross-functional,
Geographically Distributed Work**

By

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Communication, trust and performance:
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cross-functional, geographically distributed work

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Executive Summary

The purpose of this paper is to report the results of the CIFE research study of trust in cross-functional, geographically distributed A/E/C teams. Cross-functional, geographically distributed teams provide the construction industry with great advantages by bringing diverse skills to bear on problems and projects that span traditional organizational functions. Although companies are quickly adopting the model of cross-functional, geographically distributed teams, little is known about the new social environment that this creates for team members. A major challenge in such teams is the development of interpersonal trust between team members. The objective of this research is to determine the influence of geographic distribution, cross-functionality on communication, interpersonal trust and individual performance between two team members, called a dyad, in an Architecture, Engineering and Construction (A/E/C) industry setting. Our research questions were: What are the key predictors of interpersonal trust in distributed A/E/C teams? And how does interpersonal trust influence individual performance?

We hypothesized that trust is more difficult in cross-functional, geographically distributed dyads because of the different disciplinary perspectives and the lack of face-to-face interaction available when working at a distance. We also hypothesize that trust improves the work process performance of both members of the dyad, i.e. the trustor and the trustee, leading to greater work outputs, such as less time, less cost and higher quality.

To test these hypotheses we studied 224 dyads of team members in 6 design/build teams working on large building projects in the USA. The data collection was based on two types of questionnaires. We gathered individual performance data from the Project Managers. We then asked the team members about their trust relationships with four team members chosen at random from their team. The data was analyzed using correlations, multivariate regressions and structural equation modeling.

As expected we found that team members who were geographically distributed had less personal communication, which was associated with lower perceived trustworthiness and lower trust. We were surprised to find that cross-functional dyads had higher perceived trustworthiness and higher trust. We surmise that something akin to “Professional courtesy” may operate in these cases. High trust increased the work process performance of both the trustor and the trustee and resulted in higher output performance for both. Further longitudinal research is needed to determine if these relationships are significant over time. The implications of these findings for members and managers of cross-functional geographically distributed teams are mentioned briefly but will be addresses in more detail in a subsequent publication.

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Introduction

Increased competitive pressures shorten project lead times and lead to greater use of concurrent engineering and cross-functional teams. This, plus the availability of communication technologies, such as the Internet, means that these cross-functional teams are often geographically distributed.

The construction industry is known for being highly fragmented and operating through a network of formal and informal teams that are quickly assembled, widely dispersed, span organizational and national borders and consist of different cultures and disciplines.

Even the construction industry is challenged by the new Internet technology that makes it possible to assemble teams more quickly and operate over larger distances. Shortened lead times require team members to perform tasks, such as building design, structural analysis and construction planning, concurrently rather than sequentially. This requires design/build teams to operate with greater interdependence between the various disciplines, such as architecture, structural engineering and construction management.

One of the major challenges of cross-functional, distributed teams is the development of trust (Bishop, 1999, Bennis, 1999).

Cross-functional, distributed teams provide advantages in bringing diverse skills to bear on problems and projects that span traditional organizational functions. Such teams are now used in a variety of areas such as engineering (Hauptman, 1999), design (Levinthal and Warglien, 1999), nursing (Ireson, 1998), purchasing, and new product development (Brunelli, 1999). Although companies are quickly adopting the model of cross-functional, distributed teams (Jasswalla and Sashittal, 1999), little is known about the new social environment that this creates for team members (Maznevski and Chudoba, 2000).

Trust is necessary in cross-functional, distributed work because the higher interdependence between disciplines means that team members must rely on the functional expertise of other team members. However, trust may also be more difficult to establish in these teams because team members are less familiar with the methods of team members from other disciplines and geographic distance makes it more challenging to create a shared understanding (Cramton, 2000).

This research project used members of Architect, Engineering and Construction Management (A/E/C/) industry teams to validate a model of interpersonal trust that has been previously tested on A/E/C student teams in the project-based learning (PBL) learning environment at Stanford (<http://pbl.stanford.edu>).

Research questions

The goal of this research is to answer the following research questions:

- What are the key predictors of trust in cross-functional and distributed A/E/C work?
- How does trust influence team member's performance in this work?

Current state of knowledge

We define trust as the willingness of the trustor to accept the risk of relying on the trustee, even if the trustor is unable to monitor or control the trustee (Rousseau, Sitkin, Burt and Camerer, 1998, see also Mayer, Davis and Schoorman, 1995).

Hardin (2000) describes the interpersonal trust relationship in a two person dyad as "Person A trusts Person B about X", where X is the object of trust. However, along with others, we assume that trust can only exist within a particular situation or action (see Gambetta, 1988, Bhattacharya, Devinney, & Pittultia, 1998). As Bigley and Pearce (1998) have argued, it is not a question of "What is trust?" but rather "What trust and when?" Thus, we assume that the expectations of the intentions or behavior of another must be embedded in a particular situation. The situation studied in this research project is that of the cross-functional, distributed teams in the A/E/C industry.

Cross-Functional Work

A cross-functional team is, ideally, a small group of key people with complementary skills, who are chosen to achieve a common goal and are mutually accountable for the team's success (Katzenback and Smith, 1993). Developing trust may be particularly difficult in cross-functional work due to different work practices and perspectives, which make it difficult to develop perceived trustworthiness for a team member in a different discipline. For example, even though cross-functional team members work together to achieve shared project goals, different disciplines often have different functional objectives, priorities or agendas (Jasswalla and Sashittal, 1999). Thus, while the interdependence of the tasks requires trust between team members (see Shepard & Sherman, 1998), the cross-functional nature of these teams may make the development of perceived trustworthiness particularly difficult.

H1: Trustors in cross-functional dyads will have lower perceived trustworthiness for the trustee than trustors in uni-functional dyads.

Distributed Work

The challenges confronting cross-functional teams are compounded when team members are distributed around the globe and have few opportunities to interact face-to-face, rely heavily on technology to

mediate their interactions, and have cultural or language barriers. There is growing recognition of the central position trust plays in geographically distributed teams (Jarvenpaa and Leidner, 1999; Iacono and Weisband, 1997). Trust is central to teamwork, leadership and organizational culture (Fairholm, 1994; Nicholas, 1993; Ryan, 1999). A number of characteristics of distributed work could interfere with the development of perceived trustworthiness. When teams are geographically distributed, information may flow less easily between team members (Hollingshead, 1996), who may not develop the same understanding of the information that is shared (e.g. Cramton, 2000). When observing geographically distributed teams, Armstrong and Cole (1996) noted that distant team members had a more difficult time reconciling issues. Similarly, Straus and McGrath (1994) observed that distributed teams experienced more conflict than collocated ones because of the challenges they faced in sharing complex information. In addition to spanning geographic distances, these distributed teams are likely to be composed of people from different cultures (see Olson & Olson, 2002) with different basic assumptions (Schein, 1991).

We expect that these characteristics of distributed work will reduce personal communication between team members, which is used to develop perceived trustworthiness. Serendipitous social interactions are less likely to occur in distributed work. There is no virtual equivalent for an accidental meeting at the water cooler.

H2: Trustors in distributed dyads will have less personal communication than trustors in collocated dyads.

In the Social Capital literature, social interactions are proposed to be important in developing trust. We propose that the lack of social interaction inhibits the development of perceived trustworthiness, major component of trust.

H3: Trustors who have less personal communication with a trustee will have lower perceived trustworthiness for that trustee than for trustors with whom they have more personal communication.

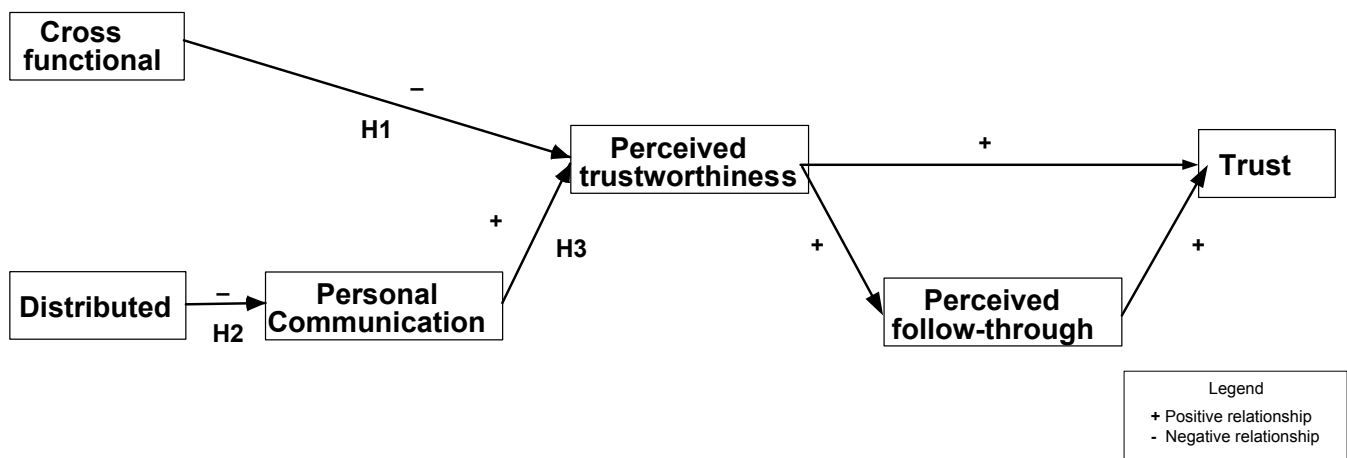
In existing models of trust, perceived trustworthiness of the trustee is an antecedent to trust for that person. Perceived trustworthiness is the individual's assessment of how much and for what type of performance another person can be trusted (Hardin, 2000). Perceived trustworthiness is generally understood as a multidimensional construct. Mishra identifies the dimensions of competence, openness, concern and reliability (Mishra, 1996). Persistence, technical competence and fiduciary responsibility are Barber's dimensions (Barber, 1983). Rempel uses predictability, dependability and faith (Rempel, 1985). We adopted the dimensions used by Mayer, Davis and Schoorman (1995) of benevolence, ability

and integrity. Benevolence means that the trustee’s goals include positive outcomes for the trustor. The concept of benevolence is similar to concepts of goal alignment or “encapsulated interest” (Hardin, 2000) and to Das and Teng’s (1998) arguments that confidence derives from mutually compatible interests. The benevolence dimension is also consistent with McAllister’s conception of affect-based trust – trust grounded in reciprocated concern from the other party. Ability means that the trustee has the skills and resources that they need to perform the task. This dimension is similar to the idea that confidence is derived from peer reliability and dependability (see McAllister, 1995). Integrity has been conceptualized in many different ways including values congruence (e.g. Sitkin and Roth, 1993), consistency (e.g. Butler, 1991), and character (e.g. Gamarro, 1978). Consistent with Mayer et al (1995), we conceptualize integrity as virtuosity and honesty as perceived by the trustor. Although the dimensions of perceived trustworthiness can be measured separately, it is perceived trustworthiness as an aggregate construct that is proposed as a major antecedent to trust (Mayer et al 1995, Hardin 2000).

Studies of trust in cross-functional, distributed work have shown that perceived follow-through mediated the relationship between perceived trustworthiness and trust (Zolin, 2002). In this context, possibly due to the difficulty of evaluating work, perceived performance is informed by initial impressions, rather than an objective evaluation of work performance. Therefore perceived trustworthiness has a direct and indirect influence on trust as shown in figure 1.

Hypotheses 1 through 3 are shown in figure 1.

Figure 1. Effect of discipline, distribution and communication on perceived trustworthiness and trust



Performance

Many people intuitively feel that higher trust for one's teammates will result in better work performance, but research has found conflicting results (Dirks, 1999, Dirks 2001). Research has shown that, rather than having a direct impact on performance, trust has a direct effect on other determinants of performance, such as organizational citizenship behavior, job satisfaction and individual job performance (Dirks, 2001) and problem solving (Klimonski, 1976). Dirks proposes two processes (2001). First, trust moderates the effects of motivation on performance by influencing one's expectations about another's likely behavior, thus increasing or reducing the trustor's motivation and output performance. Secondly, trust may also moderate the relationship between the trustee's performance and the trustor's perception of follow-through, such that higher trust would result in higher perceived follow-through independent of actual performance (Dirks, 2001). Thus, the trustor with higher trust will have a higher perception of the trustee's follow-through and job performance than a more objective observer, such as the Project Manager.

H4: The relationship between the trustor's motivation and output performance is moderated by trust.

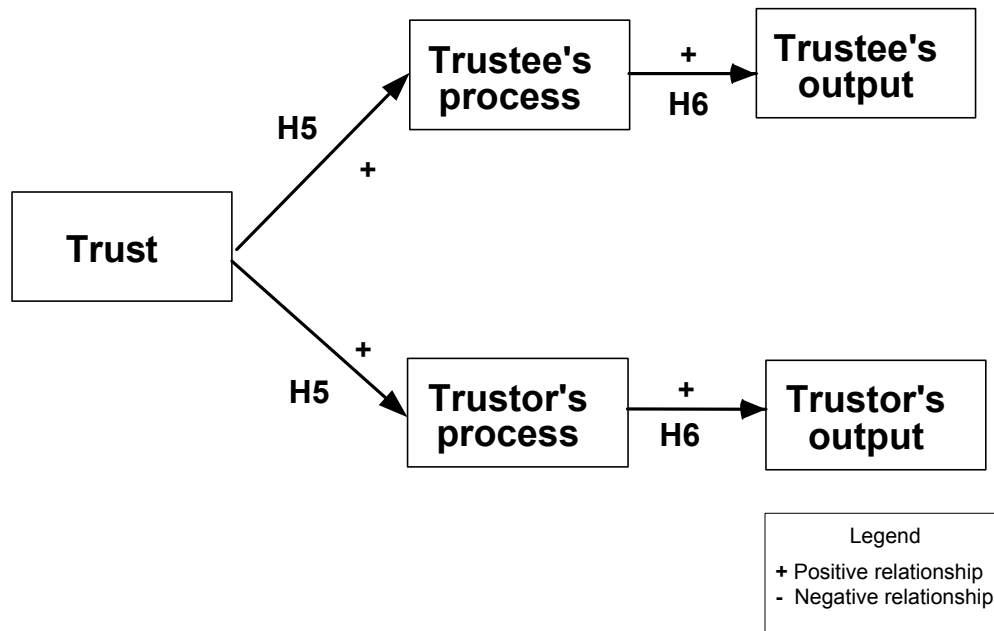
Dirks also proposes that in high trust groups, motivation is directed toward group processes, while in low trust groups motivation is directed towards individual efforts. We can apply this team level concept to the interpersonal level of trust between two people in a dyad. In a dyad it is also possible that being trusted could affect the trustee's work processes and ultimately work output. For example, someone who feels trusted may contribute more ideas and thus have higher work output. In a dyad trust could also influence the trustor's work process and performance. For example, a trustor who trusts a team member may be more flexible and provide more information resulting in faster, better, cheaper work outputs. Therefore, in contrast to hypotheses 4, alternative hypotheses for the relationship between trust and performance could be:

H5: For both the trustor and the trustee, trust is positively related to work process.

H6. Also for both the trustor and the trustee, work process is positively related to output performance.

Hypotheses 5 and 6 are shown in figure 2.

Figure 2. Effect of trust on trustor's and trustee's work process and output performance



Research methodology

To evaluate the antecedents and effects of interpersonal trust in cross-functional, distributed teams we studied 96 team members of six design/build teams working for Swinerton, Incorporated in the construction industry in the USA. The teams were all working on large multi-million dollar projects, involved in buildings such as a concert hall, a resort complex, or a university student union building. The teams had an average of 15 core team members. All teams included members with different disciplines such as architecture, structural engineering, construction management, electrical engineering and mechanical engineering. Team members typically belonged to different organizations. Typically one or more owner's representatives represented the client firm on each teams. As the general contractor, Swinerton provided the project management and administrative staff. Subcontracting firms provided most of the professionals with specialized skills, such as architecture or engineering. Most team members worked from their company's office, although approximately one quarter worked on site.

Data collection

We first conducted telephone interviews with the project managers. The objectives of the interviews were to brief the project managers on the survey, to gather background information on the teams and to agree upon a plan to measure the quality of team and individual work processes and performance.

We then asked the project managers to complete a survey that gathered information about the performance of the team and the team members. All Project Managers completed the survey for all teams and all team members (see questionnaire in Appendix 1).

The team members were then asked to complete an online survey to gather information about their working relationships with other team members and their own demographics, such as gender, discipline and work location (see questionnaire in Appendix 2). Because we were following the formulae of “A trusts B about X”, our unit of analysis was the directional dyad, i.e. in each dyad of A and B there are two directional relationships; there is A’s trust for B and B’s trust for A. Each team member was asked to report on their relationship with four other team members who were chosen at random from the team. We received useful responses from 54 team members resulting in a response rate of 56%. This resulted in observations of 224 directional dyads. If a team member did not answer the survey, the Project Manager reported on the primary work location and the primary and secondary disciplines for that team member.

Dependent Variables: The dependent variables of interest in this study are trust, work process performance and work output performance.

Trust was measured using a scale developed by Mayer and Davis (1999), which we converted from team level trust to interpersonal trust (see appendix 2). Our measures of trust resulted in a reasonable scale reliability of $\alpha = .65$, and loaded on one component.

Performance measures Our challenge in measuring work performance was to find measures that were applicable across disciplines and easily available. This suggested the use of performance measures that were broad in time span, general rather than discipline specific, close to the organization’s goals (Smith, 1976) and based upon judgment rather than measurement (Landy and Farr, 1983). We measured work performance at the individual and team level, but not the organizational level (Brannick and Prince, 1997). We measured both the work processes and work outputs but not work inputs (Brannick and Prince, 1997). We used the Project Manager’s judgments of individual and team flexibility, provision of information, problem solving and creativity to measure work process performance (see appendix 1). Our measure of individual work process resulted in a scale reliability of $\alpha = .78$, loading on 1 component. We used the Project Manager’s judgment of individual and team time, cost and quality as measures of work output performance (see appendix 1). Our measure of individual output performance resulted in a scale reliability of $\alpha = .90$, loading on 1 component.

Independent Variables: The independent variables of interest in this study are propensity to trust, distribution, cross-function, communication topic, perceived trustworthiness, and perceived follow-through (see appendix 2) for survey questions).

Propensity to trust was measured using the Rotter scale for general trust (1971) modified by Yamagishi, Cook and Watabe (1998) (see appendix 2). The answers to these questions were reported on a 7-point Likert scale. Our measures of trust propensity resulted in a scale reliability of $\alpha = .55$, loading on three components.

Communication topic. A number of measures of communication were collected including communication about the project, communication about coordination, and communication about personal matters. The answers to these questions were reported on a 7-point Likert scale.

Perceived trustworthiness was measured using dimensions of benevolence, ability and integrity from the Mayer and Davis scale (1999). The answers to these questions were reported on a 7-point Likert scale. Our measures of perceived trustworthiness (see appendix 2) resulted in a scale reliability of $\alpha = .94$, loading on two components.

Task interdependence is the extent to which a team member must rely upon another team member to accomplish his or her task. We used the Job Characteristics Index, (Sims, Szilagyi and Keller 1976 reported in Galup, Saunders, Nelson and Cerveney, 1997) to measure task interdependence. The answers to these questions were reported on a 7-point Likert scale. Our measures of task interdependence resulted in a scale reliability of $\alpha = .89$, loading on one component.

Perceived follow-through is the trustor's perception of the extent to which the trustee performed as expected. Follow-through is measured by an index of four items (see appendix 2). The answers to these questions were reported on a 7-point Likert scale. Our measures of perceived follow-through resulted in a scale reliability of $\alpha = .83$, loading on one component.

Cross-functional. We asked team member to report their primary and secondary disciplines. If the dyad partners did not share either a primary or secondary discipline they were considered to be cross-functional and coded equal to 1, others were coded equal to 0.

Distributed. We asked team members to report their primary work location. If the primary work location was not the same, the dyad was considered distributed and coded as a 1. If primary work location was the same the dyad was considered collocated and coded as a 0.

Data Analysis

Statistical data analysis was used to test the relationships between the variables. We calculated correlations between all variables. In that analysis we observed that several variables were significant in predicting both perceived trustworthiness and trust. We conducted mediation analyses to determine if which variables might have a direct relationship to trust and which were mediated by perceived trustworthiness (Baron and Kenney, 1986). We used the information from that analysis to select variables for multivariate regressions analysis predicting perceived trustworthiness. To test our hypotheses about distributed and cross-functional dyads, we compared the means, and F-statistic for collocated dyads compared to distributed dyads and uni-functional dyads compared to cross-function dyads.

From those results we constructed a structural equation model predicting trust and another predicting work output performance. We used the estimation procedure of AMOS (Hoyle, 1995, Byrne, 2001) to construct the structural equation models (SEM) because they can simultaneously observe the effects and changes of the variables in the model. To test our model of the relationships between the variables of interest, we adopted a strictly confirmatory analysis approach (Joreskog, 1993). The AMOS SEM provides a number of tests to measure the goodness of fit between the data and the proposed model. The Measures include the chi-squared and degrees of freedom of the model, the probability that the model can be replicated (p) and a number of fit indices, such as NFI, CFI, RFI and RMSEA (these measures are described in the glossary)

Results

The descriptive statistics for the quantitative variables are reported in table 1. On the whole participants reported high levels of trust ($M = 4.5$, $SD = 1.3$ on a 7 point scale), task interdependence ($M = 4.4$, $SD = 1.68$ on a 7 point scale) and motivation ($M = 5.9$, $SD = .8$ on a 7 point scale). The number of hours per week spent face to face was on average 4.0, but the standard deviation was high (9.3). This is not surprising because trustors were asked to report on their relationship with trustees who were chosen at random. Consequently there would be a large variation in the need for communication between randomly chosen team members, since some might be highly interdependent and others may not. As we would expect there was a highly significant positive correlation between task interdependence and hours spent face to face ($r = .36$, $p < .000$) (see table 2), meaning that the more team members had to rely on each other the more time they spent in direct communication.

The Project Managers were asked to rate their team as a whole across the seven performance dimensions that represent team process and team performance. The Project Managers' assessments of team performance show that, on average the Project Managers rate the team performance highly. No team was rated less than a 4 out of 7 on any dimension. Teams were rated highest for their flexibility (6.2), quality of performance (6) and problem solving abilities (6). The lowest rated dimensions were provision of timely and relevant information (4.6), timeliness (5) and ability to stay within budget (5.8).

Table 1. Means and standard deviations for variables

Variable	Mean	Std. Dev.
Trust	4.51	1.31
Trust Propensity	4.21	0.96
Distributed	0.76	0.43
Cross-functional	0.47	0.50
Task Interdependence	4.45	1.68
Project communication	5.21	10.66
Coordination communication	2.25	4.13
Personal communication	0.96	2.01
Perceived trustworthiness	5.37	1.09
Perceived follow-through	5.10	1.32
Trustor's output	5.04	0.93
Trustor's process	5.02	0.99
Trustee's output	4.98	1.08
Trustee's process	4.96	1.15
Perceived process	5.10	1.29
Motivation	5.90	0.78
Trust X Motivation	26.56	8.56

The Project Managers were also asked to rate each individual team member's performance across the seven same process and performance dimensions. There was an even spread of ratings ranging from 2 to 7 on all dimensions. Some individuals were rated as low as 2 on some dimensions. At the same time some individuals received high ratings of 7 on some dimensions. On average the individual team members were rated highest for their quality (5.5), followed by flexibility (5.2), creativity (5.1) and problem solving ability (5.1). The lowest rated dimensions were the same as those for team performance: ability to stick to the budget (4.3), timeliness (4.6) and provision of information (4.6). The correlations for the quantitative variables are reported in table 2.

Table 2. Correlations for Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Trust														
2. Trust Propensity	.09													
3. Distributed	-.11	-.15*												
4. Different discipline	.12+	.09	.19**											
5. Task interdependence	.24**	.00	-.22***	.00										
6. Project communication	.02	.00	-.21**	.01	.41***									
7. Coordination communication	-.01	.05	-.14*	-.07	.40***	.70***								
8. Personal communication	.13+	-.09	-.16*	-.04	.35***	.55***	.46***							
9. Perceived trustworthiness	.77***	.13+	-.13+	.15*	.30***	.06	.02	.22**						
10. Perceived follow-through	.63***	.08	-.19**	.06	.14+	.06	-.04	.13+	.71***					
11. Trustor's output	.06+	-.17*	.02	.00	.12+	.17*	.14*	.14*	.01	-.10				
12. Trustor's process	.26***	.10	-.01	.02	.14+	.18**	.17**	.17*	.11	-.02	.79***			
13. Trustee's output	.13+	-.06	.00	-.14*	-.08	-.03	-.11	-.11	.14+	.15*	.00	.02		
14. Trustee's process	.15*	-.04	.05	-.08	-.14+	-.09	-.12+	-.08	.14+	.10	-.01	.05	.85***	
15. Motivation	.10	.27***	-.10	.07	.07	-.03	-.03	-.02	.12	.06	.05	.15*	-.09	-.04

*** p <.001, ** p <.01, * p <.05, + p < .10

As expected there was a high correlations between task interdependence and all three topics of communication; project communication, coordination communication and personal communication (see table 2). There are also significant correlations between the three topics of communication and the trustor's output and the trustor's work process.

H1: Trustors in cross-functional dyads will have lower perceived trustworthiness for the trustee than trustors in uni-functional dyads.

We gathered information relating to hypothesis 1 from the correlations (table 2) and multivariate regressions (see table 3) and then used a comparison of the F-statistic to test the hypothesis (se table 4). In table 2 the correlation between different discipline in column 4 and perceived trustworthiness in row 9, has a positive correlation coefficient of $r = .15$, and that is significant at the $p < .05$. This positive relationship between different discipline and perceived trustworthiness is contrary to hypothesis 1, which proposes that trustors in cross-functional dyads will have lower perceived trustworthiness. In multivariate regression models of perceived trustworthiness (See models 2, 4, and 6 in table 3) we found that in Models 2 and 4, different discipline had a barely significant positive relationship to perceived trustworthiness. In Model 6, when perceived follow-through was added to the model, the relationship was positive and significant ($\beta = .11$, $p < .05$), providing mixed support for hypothesis 1.

Table 3. Comparison of OLS estimates (standardized beta values) of perceived trustworthiness

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Intercept	***	***	***	***	**	***
Trust Propensity	.15	.15*	.18**	.18**	.12*	.10*
Distributed	-.06		-.05		.07	
Different discipline		.14+		.13+		.11*
Task interdependence	.30***	.30***	.32***	.31***	.25***	.24***
Communicate project			-.09	-.09	-.13+	-.15*
Communicate coordination			-.18+	-.17+	-.03	-.02
Communicate personal			.26***	.27**	.18**	.18**
Perceived follow-through					.67***	.65***
Adj. R-squared	.10	.11	.15	.16	.58	.58
Model F	8.06***	8.53***	6.59***	6.67***	36.81***	35.81***
Degrees of freedom	3, 185	3, 176	6, 182	6, 173	7, 175	7, 166

*** $p < .001$, ** $p < .01$, * $p < .05$, + $p < .10$

Next we compared the mean level of perceived trustworthiness for trustors in dyads that were uni-functional to those that were cross-functional. Trustors in dyads with the same discipline had lower mean perceived trustworthiness of 5.2 compared to 5.5 for dyads with the same discipline. The F-statistic indicates that this is a significant difference, disconfirming hypothesis 1 ($F=4.26$, $p < .05$).

Table 4. F-statistic for the comparison of means between cross-functional / uni-functional dyads and distributed / collocated dyads.

	Uni/Cross-functional		Distributed/collocated	
Distributed	7.96	**	Task interdependence	10.61***
Hours F2F	5.49	*	Communicate project	9.84**
Perceived trustworthiness	4.26	*	Cross-functional	7.96
Trustee's Output	4.16	*	Perceived follow-through	7.42**
Trust	3.03	+	Hours F2F	6.53**
Trustee's Process	1.24		Communication personal	5.63*
Communicate coordination	0.90		Trust Propensity	5.38*
Perceived follow-through	0.77		Communicate coordination	4.19*
Trust Propensity	0.72		Perceived trustworthiness	3.21*
Communication personal	0.28		Trust	2.3+
Trustor's Process	0.05		Trustee's Process	0.55
Communicate about project	0.01		Trustor's Output	0.05
Task interdependence	0.00		Trustor's Process	0.01
Trustor's Output	0.00		Trustee's Output	0.00

H2: Trustors in distributed dyads will have less personal communication than trustors in collocated dyads.

WE collected information relating to hypothesis 2 from correlations (see table 4) and used the F-statistic comparison to test hypothesis 2 (see table 5).

There was a significant negative correlation between distributed dyads and personal communication ($r = -0.16, p < .05$), (see table 4). This supports hypothesis 2, that being distributed reduces personal communication.

The average for personal communication reported by trustors in collocated dyads was 1.5 compared to only 0.8 reported by trustors in distributed dyads. The F-statistic indicates that the difference was significant ($F=5.63, P < .05$), providing additional support for hypothesis 2 (see table 4).

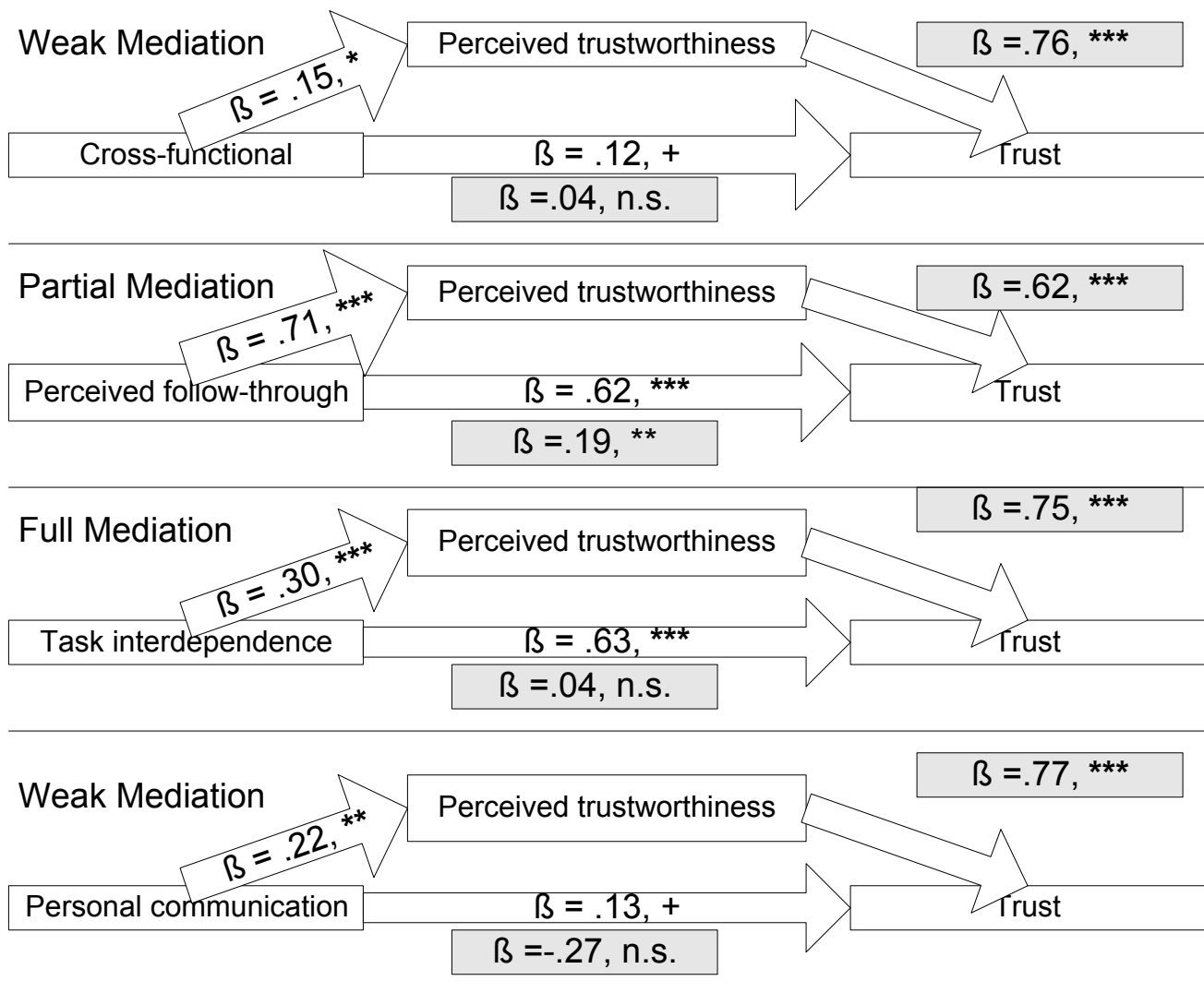
H3 Trustors that have more personal communication with the trustee will have higher perceived trustworthiness than trustors who have less personal communication.

Hypothesis 3, which proposes a relationship between personal communication and perceived trustworthiness is tested using a multivariate regression analysis, but supporting information is also gathered from correlations and a mediation analysis.

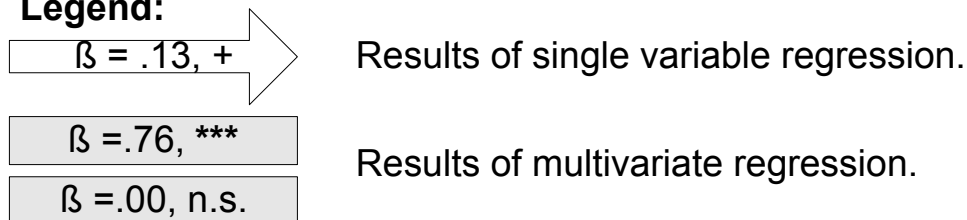
Personal communication was significantly correlated with perceived trustworthiness ($r = .22, p < .01$), which supports hypotheses 3 (see table 2). In regression models predicting perceived trustworthiness, personal communication was highly significant (see Models 3, 4, 5 and 6 in table 3) providing further support.

But a number of variables including personal communication, propensity, distribution, different discipline, perceived follow-through and task interdependence had significant relationships with both perceived trustworthiness and trust (see table 2). This raised the question of whether variables, such as personal communication, had a direct effect on perceived trustworthiness or on trust. We conducted mediation analysis for each of the variables (Baron and Kenney, 1986) (see figure 5). Personal communication, propensity, distribution, different discipline, and task interdependence were partially or fully mediated by perceived trustworthiness in their effect on trust. This means that those variables, including personal communication, affect perceived trustworthiness and through perceived trustworthiness have an effect on trust. They do not have a direct effect on trust. Only perceived follow-through maintained a significant effect upon trust when combined in a regression model with perceived trustworthiness.

Figure 5. Mediation analyses for perceived trustworthiness and trust



Legend:

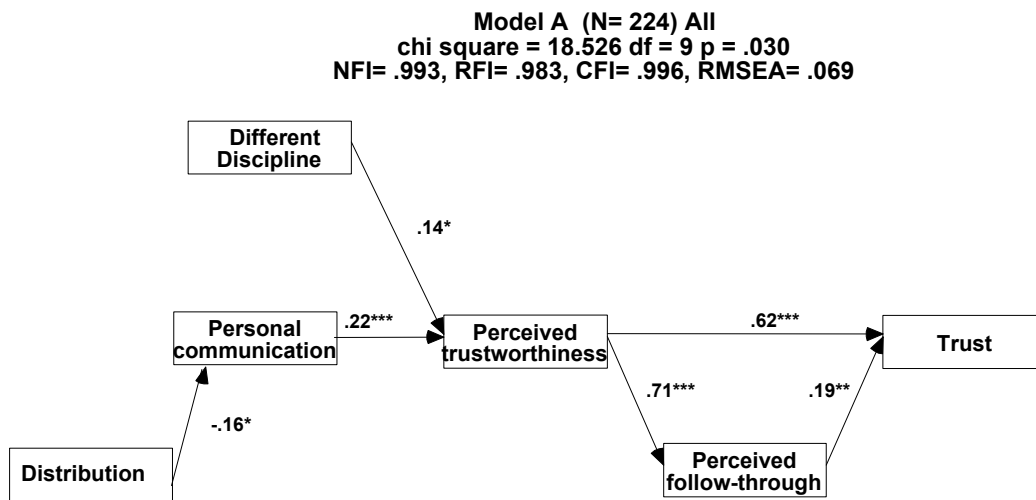


*** $p < .001$, ** $p < .01$, * $p < .05$, + $p < .10$

Structural equation modelling – Hypothesis 1, 2 and 3

To test our theoretical model of hypotheses 1 to 3 (see figure 1), we constructed structural equation models to test the goodness of fit between our theoretical model and the data (see model A, figure 6). This model has a weak fit with χ^2 (df=9) = 18.526, $p = .03$, as evidenced by these measures of the goodness of fit NFI= .993, RFI= .983 (values over .95 indicate a good fit), CFI= .996 (values over .9 indicate good fit) and RMSEA = .069 (values less than .05 indicate a good fit). In the model, dyads with different discipline were associated with higher perceived trustworthiness, providing additional evidence disconfirming hypothesis 1. In contrast, as we proposed being distributed reduced personal communication, providing additional support for hypothesis 2. As expected in hypothesis 3, personal communication increased perceived trustworthiness in model A.

Figure 6. Structural equation models of trust for all dyads (A)

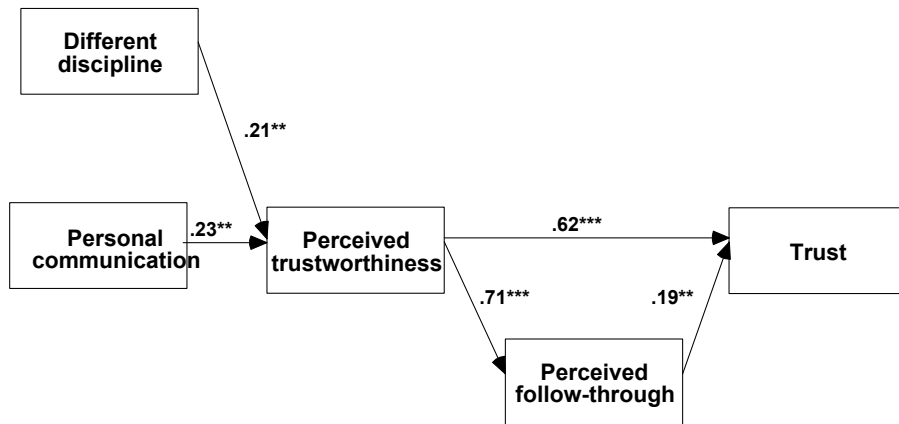


*** $p < .001$, ** $p < .01$, * $p < .05$, + $p < .10$

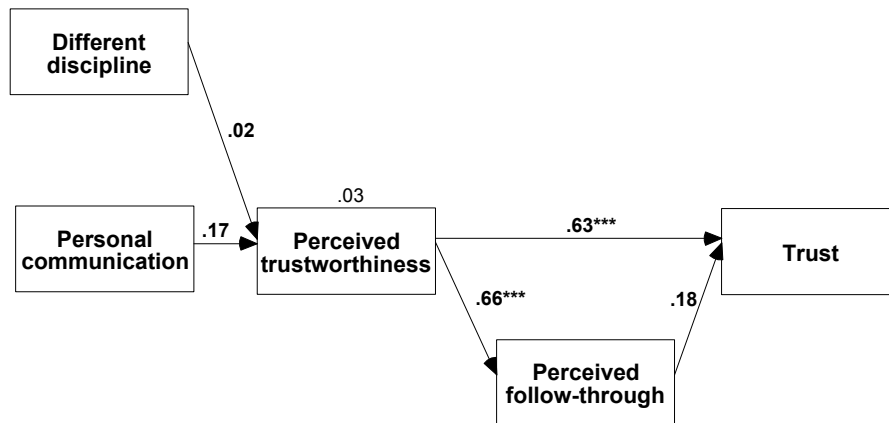
To test the hypothesis that the theoretical model is particular to distributed dyads, we tested it on distributed dyads only and collocated dyads only (see models B and C in figure 7). With distributed dyads the model had a strong fit with χ^2 (df=5) = 3.771, $p = .583$, as evidenced by these measures of the goodness of fit NFI= .998, RFI= .993, CFI= 1.0 and RMSEA = .000. With collocated dyads the model had a significantly poorer fit with χ^2 (df=5) = 14.544, $p = .012$, as evidenced by these measures of the goodness of fit NFI= .973, RFI= .920, CFI= .982 and RMSEA = .192. The only significant relationships were between perceived trustworthiness and trust ($\beta = .63$, $P < .001$) and between perceived trustworthiness and perceived follow-through ($\beta = .66$, $p < .001$).

Figure 7. Structural equation models of trust for distributed dyad (B) and collocated dyads (C)

Model B (N= 171) Distributed
 chi square = 3.771 df = 5 p = .583
 NFI= .998, RFI= .993, CFT= 1.000, RMSEA= .000



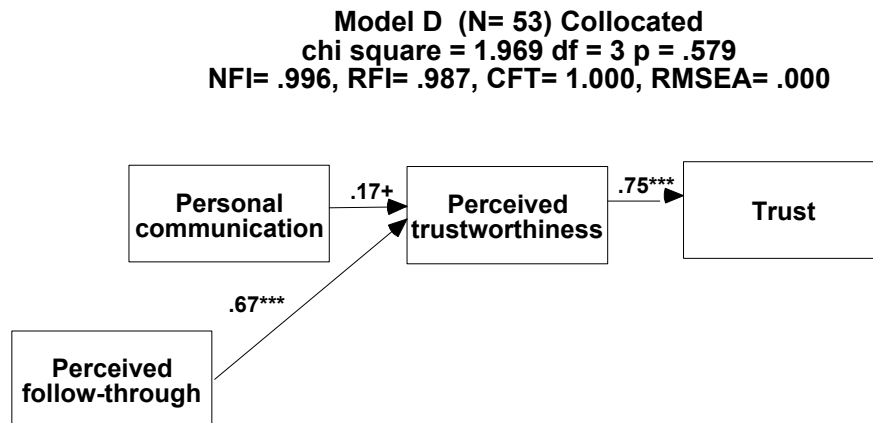
Model C (N= 53) Collocated
 chi square = 14.544 df = 5 p = .012
 NFI= .973, RFI= .920, CFT= .982, RMSEA= .192



*** p < .001, ** p < .01, * p < .05, + p < .10

A better fitting model for collocated dyads was model D (see figure 8) with χ^2 (df=3) = 1.969, $p = .579$, as evidenced by these measures of the goodness of fit NFI= .996, RFI= .987, CFI= 1.0 (values over .9 indicate good fit) and RMSEA = .000. In this model does not have the mediating relationship and perceived follow-through affects perceived trustworthiness, which in turn affects trust.

Figure 8. Structural equation models of trust modified for collocated dyads (D)



*** $p < .001$, ** $p < .01$, * $p < .05$, + $p < .10$

H4: The relationship between the trustor’s motivation and output performance is moderated by trust.

To test the hypothesis that the relationship between motivation and output performance is moderated by trust we created a variable to represent the interaction between trust and motivation (Trust X Motivation) and used it in a regression model to predict trust (see table 7). In model 1 (see table 5) we did not find a significant relationship with the trustor’s work process and trust ($\beta = .10$, n.s.), motivation ($\beta = .06$, n.s.) or the interaction between trust and motivation of ($\beta = .15$, n.s.). Similarly, in model 2 there was no significant relationship between the trustor’s output performance and trust ($\beta = .30$, n.s.) motivation ($\beta = .17$, n.s.) or the interaction between trust and motivation ($\beta = -.29$, n.s.) (See table 4), thus disconfirming hypothesis 4. This is similar to findings in other studies, where the relationship between motivation and trust is only sometimes mediated by trust (Dirks, 1999).

Table 5. Comparison of OLS estimates (standardized beta values) of trustor's process and output performance

	Model 1	Model 2
	Trustor's Process	Trustor's ...Output ...
Intercept	+	+
Trust	.10	.30
Motivation	.06	.17
Trust X Motivation	.15	-.29
Adj. R-squared	.06	-.01
Model F	5.09	0.45
Degrees of freedom	3, 189	3, 189

*** $p < .001$, ** $p < .01$, * $p < .05$, + $p < .10$

H5: For both the trustor and the trustee, trust is positively related to work process.

We used correlations to test hypothesis 5. The relationship between trust and the trustor's process performance was highly significant ($r = .26, p < .001$) (see table 2) and the relationship between trust and the trustee's work process ($r = .15, p < .05$) was also highly significant. This supports hypothesis 5, that trust also improves both the trustor's and the trustee's work process.

H6 For both the trustor and the trustee, work process is positively related to output performance.

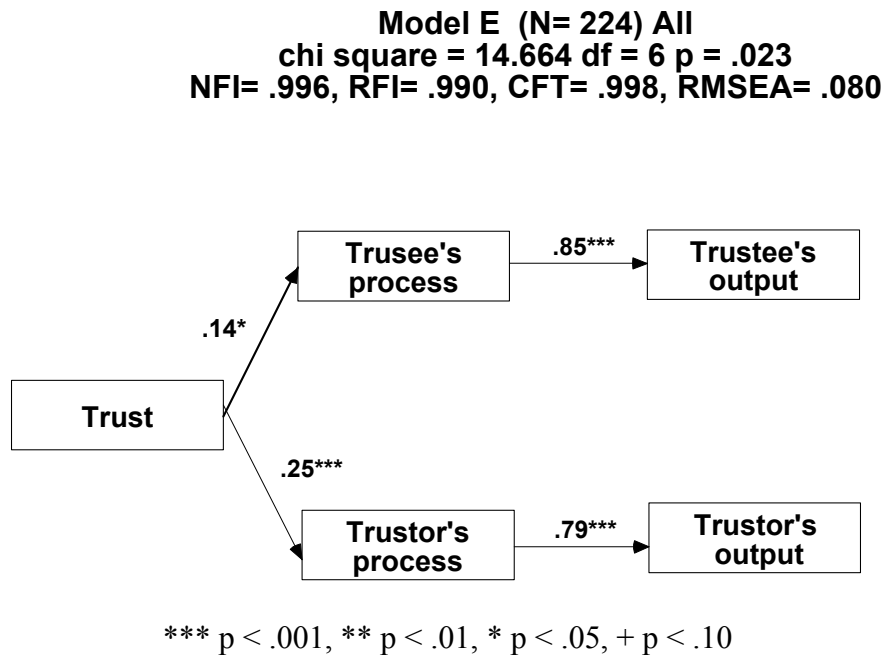
Correlations were also used to test hypothesis 6. There was a highly significant positive relationship between work process and work output for both the trustor ($r = .79, p < .001$) and the trustee ($r = .85, p < .001$) providing strong support for hypothesis 6.

Structural equation modelling – Hypothesis 4, 5 and 6

When the relationships described in hypotheses 5 and 6 were combined in a structural equation model, the relationships between the variables remained significant and the model demonstrated a good fit to the data with $\chi^2 (df=6) = 14.664, p = .023$, as evidenced by these measures of the goodness of fit $NFI = .996, RFI = .990, CFI = .998$ and $RMSEA = .08$. (see figure 9, model E). This supports hypotheses 5 and 6, that trust improves trustee and trustor's work process, which, in turn, improves work output.

It appears that, rather than mediating the relationship between motivation and performance, trust influences the work process, which affects the work output performance.

Figure 9. Structural equation model of the effects of trust and on the trustor’s and trustee’s process and output performance.



Discussion

As expected we found that geographic distributed reduces personal communication, which in turn reduces perceived trustworthiness and results in lower trust.

It is interesting that of the three topics of communication that we measured, only personal communication has a significant relationship with perceived trustworthiness. This supports theories of trust that recognize the importance of social activities in the development of personal relationships to facilitate trust and cooperation. For example, Homans’s Theory of Group Formation (1950) predicts that shared activities increase interactions, which create shared sentiments.

Contrary to hypothesis 2, we found that cross-functional dyads had higher perceived trustworthiness than uni-functional dyads. It is possible that a “Professional courtesy”, possibly similar to *Swift Trust* operates in cross-functional dyads. *Swift Trust* (Meyerson, 1996) is the use of roles to establish trust in situations such as fast start teams. When dealing with someone with a different discipline, a team member may trust the role rather than the person. This could be the basis for professional respect or

politeness. The trustor in a cross-functional dyad gives the benefit of a doubt to team member with a different discipline. Whether this is a good idea or not would depend upon the trustworthiness and actual performance of the trusted team member. If the team member is capable, reliable and honest, extending higher perceived trustworthiness is good. But if the team member is not trustworthy, this could lead to lower performance. If team members are selected to ensure high levels of ability and monitored for performance, then high levels of professional respect avoids potential problems caused by a lack of trust between cross-functional team members. If team members have variable levels of expertise compared to the complexity of their tasks and the Project Manager does not monitor performance closely, then high levels of professional respect could lead to lower quality performance. Another question that could be asked, is how durable is Professional courtesy? Is it a fragile effect that could disappear when challenged? More research is needed to compare professional respect with the relative level of control, task complexity and trust.

Although we did not hypothesize about task interdependence, we were surprised when task interdependence was positively associated with perceived trustworthiness and trust. This indicates that the higher the task interdependence between team members, the higher the perceived trustworthiness and trust. We expected that higher task interdependence would be associated with higher risk and that higher risk would reduce trust. Maybe high task interdependence also increases the benefits associated with exercising trust, providing team members with opportunities to discover the trustworthiness of their partners and to develop trust. Thus the more team members exercise trust successfully, the more trust develops. More research is needed to investigate the processes operating with respect to task interdependence and trust.

Trust was associated with cross-functional dyads, task interdependence, perceived follow-through and personal communication (see table 2). When perceived trustworthiness was added to the models predicting trust, task interdependence was no longer significant. This indicates that task interdependence and personal communication influence perceived trustworthiness and perceived trustworthiness influences trust. Thus we see a pattern in which the situational factors of discipline and task interdependence influence perceived trustworthiness, which then impacts on trust. The order of these relationships was confirmed in our mediation analyses (See figure 5) and structural equation models (see figures 6 through 8).

Limitations of the research

Despite strong evidence supporting the proposed relationships, it is not possible to prove causal relationships but we can find indications of the direction of the variables' influences. For example, we see a strong relationship between trust and the trustor's work process, being flexible, providing information, problem solving and being creative. We cannot tell if having trust creates a social environment that promotes those work processes or if a person with good work processes finds it easier to trust. Now that this and other relationships have been identified, a longitudinal study might be able to determine these relationships.

A limitation of this study is the lack of a longitudinal comparison. Trust develops and changes over time and therefore any study that does not measure trust over time is limited in its ability to test and identify causal relationships. Unfortunately, the limited time workers have available to participate in research and the difficulty of attracting the same respondents at two points in time makes longitudinal studies extremely difficult in work related studies. Additional longitudinal research is required using industry respondents to test these relationships over time.

Conclusion

Increased global competitiveness and the use of Internet technology, vastly increasing the use of cross-functional, geographically distributed teams. These factors create a new working environment that could strain our ability to develop interpersonal trust.

As anticipated, we found that distributed dyads had less trust than those who were collocated. This could be, as proposed by McEvily & Wilson (In press), not lower trust but slower trust development. Since our study was not longitudinal we cannot test that theory, but our teams had been operating for more than a year and the trust in distributed dyads was still significantly lower than that in collocated dyads. If the theory of slower trust in distributed teams is true, since many project teams have a limited time frame, some project teams could disband before the distributed dyads had developed trust to the same extent as the collocated dyads in the team.

Contrary to expectations, this study indicates higher perceived trustworthiness, and consequently higher trust, between team members of cross-functional dyads. We proposed that cross-functional dyads experience greater difficulty in evaluating the performance of team members. In the face of this difficulty, social rules such as professional courtesy could be substituted for performance evaluation in making the trust decision. This process provides the benefit of facilitating cooperation and the

achievement of team goals in the face of insufficient information about the performance of cross-functional team members, but that introduces an additional risk. If the trusted team member is trustworthy, i.e. has the skills, benevolence toward other disciplines and team goals and also has integrity a positive decision to trust is likely to be a good decision. But, if the team member is under skilled, has goals that override team goals or is lacking in integrity, a positive trust decision has a higher risk of leading to a failure to follow-through. In a cross-functional team where evaluating team member's performance is difficult that could lead to poor quality of work and a delay in identifying the failure in performance. More research is required to determine if higher trust for cross-functional team members is sometimes associated with lower performance.

We also found that increased task interdependence increases trust. We propose that, if the need to trust is strong enough to overcome the potential risks, trust will be exercised and develop more so than if the need did not exist. Therefore situations that require trust, such as higher task interdependence, create opportunities to exercise trust and could lead to higher trust.

This study extends the model of interpersonal trust that we tested in cross-functional, global student teams (Zolin, 2002) to show that trust influences the work process and work output performance of both the trustor and the trustee.

Although the results of the A/E/C student teams (Zolin, 2002) and the industry A/E/C teams cannot be directly compared, we would like to mention in general some interesting differences between the two studies. In the previous study of student A/E/C teams we found that perceived follow-through mediated the relationship between perceived trustworthiness and excessive checking, which could be called a lack of trust. This means that the trustor's in cross-functional, distributed dyads used perceived trustworthiness to evaluate their team member's follow-through. We propose that because performance information may be harder to find in distributed dyads and because performance may be difficult to evaluate in cross-functional dyads, trustors used their initial impressions rather than observations or other information to evaluate follow-through. We found the same mediated relationship in the industry teams. More study is needed to determine the causes of this effect.

In conclusion this study has identified the effects of cross-function and distribution on interpersonal trust and the effect of trust on work process and outcome performance. This knowledge can be used as the basis of trust development programs and training in the construction industry.

This work can be used to inform future CIFE research activities in areas such as:

- 1. COLLABORATION TECHNOLOGIES:** Trust is very important in the capture, sharing, management and reuse of information and knowledge. The concepts and theories of trust can be used to analyze collaboration technologies and suggest improvements and opportunities.
- 2. VDT:** The Virtual Design Team (VDT) simulation is a mature, robust and established simulation technology that has been developed over the last ten years was initiated with CIFE funding. Currently VDT can model goal incongruence between team members (Thomsen, Levitt and Nass, 1998) but it operates on the assumption that different levels of trust between team members have no effect on the project performance. A future goal of this research is to design, specify and implement changes to the VDT simulation to allow for predictions that incorporate differences in the levels of trust in workgroups.
- 3. E-COMMERCE:** Trust and trustworthiness are key issues in Internet commerce. E-commerce sites, computer-based sales representatives (advisors), reputation systems, avatars and other tools will require a theoretical logical, and empirically tested operationalization of trust to be optimally effective.
- 4. PBL:** Being involved in an authentic project based learning experience of a virtual team, the students participating in the PBL class CEE222/122 are subject to the challenges to trust experienced in global AEC teams. The trust model and guidelines to build, maintain, and repair trust will provide key input to the CEE222/122 students and help them accelerate and improve their trust relations with their remote team members.

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Glossary

Alpha	Alpha is Cronbach's reliability coefficient, which is a measure of a scale's reliability based upon internal consistency of the items in the scale.
B	" β " is the coefficient of the relationship between two variables in a regression analysis. If $A = 2 * B$, then $B's r = 2$.
CFI	Comparative Fit Index. The comparative fit index (CFI; Bentler, 1990) compares the fit of an AMOS model to a baseline model. CFI values close to 1 indicate a very good fit.
F-statistic	The F-statistic is used for testing if a difference exists between one or more means.
Likert scale	A Likert scale is a method of measuring answers to questions using a scale of 1 to 7.
M	Mean is a method of computing the average for a variable.
NFI	Normed Fit Index. The Bentler-Bonett (1980) normed fit index measures the fit of an AMOS model. A NFI of .966 means that the model has a discrepancy that is 96.6% of the way between the (terribly fitting) independence model and the (perfectly fitting) saturated model. "...models with overall fit indices of less than .9 can usually be improved substantially." (Bentler and Bonett, 1980, p. 600)
p	"p" is the probability that the null hypothesis, the variables are not related, is correct. In other words, if you are testing the relationship between variable A and variable B, a p value of .05 means that there is a 5% chance that the variables are not related.
R	"r" is the coefficient of the relationship between two variables in a correlation analysis. If $A = 2 * B$, then $B's r = 2$.
RFI	Relative Fit Index. Bollen's (1986) relative fit index compares the fit of an AMOS model to a baseline model. RFI values close to 1 indicate a very good fit. Byrne (2001) reports that a value above .95 in the RFI index indicates superior fit.

RMSEA	Root mean square error of approximation. Unlike other measures of fit for AMOS models that tend to favor models with many parameters, RMSEA is an index of model fit that compensates for the effect of model complexity. “Practical experience has made us feel that a value of the RMSEA of about .05 or less would indicate a close fit of the model in relation to the degrees of freedom. ... We are also of the opinion that a value of about 0.08 or less for the RMSEA would indicate a reasonable error of approximation and would not want to employ a model with a RMSEA greater than 0.1.” (Browne and Cudeck, 1993)
SD	Standard deviation is the average amount by which a group of numbers varies from the mean for the group.

Appendix 1. Project Managers' Survey Questions

Team output performance:

Compared to other teams you have worked with, how well do you think this team is currently performing along the following dimensions?

Timeliness of delivery – this team delivers on time

Reasonable costs – this team stays within budget

Quality of performance – this team performs to high standards

Team process performance:

Flexibility – this team accommodates requests for changes

Information – this team provides timely and relevant information

Problem solving – this team finds practical solutions to problems

Creativity – this team makes creative suggestions

Team member output performance:

Please rate this team member on the extent to which he or she has fulfilled the following goals:

Timeliness – this team member delivers on time

Reasonable cost – this team member stays within budget

Quality of performance – this team member performs to high standards

Team member process performance:

Flexibility – this team member accommodates requests for changes

Information – this team member provides timely and relevant information

Problem solving – this team member finds practical solutions to problems

Creativity – this team makes creative suggestions

Appendix 2. Team Member Survey Questions

General trust (Rotter, 1970)

One should be very cautious with strangers.

Most people can be counted on to do what they say they will do.

These days, you must be alert or someone is likely to take advantage of you.

Most salespeople are honest in describing their products.

Most people answer public opinion polls honestly.

Most adults are competent at their jobs.

Task Interdependence (Sims, Szilagyi and Keller, 1976 reported in Galup dt al, 1997))

To what extent does your job depend upon your ability to work with this team member?

To what extent is dealing with this team member a part of your job?

To what extent do you receive feedback from this team member?

To what extent does your work rely on work that has been done by this team member?

To what extent does this person rely on work that has been done by you?

Trust (Based upon Mayer and Davis, 1999)

If I had my way, I wouldn't let this person have any influence over issues that are important to me.

I would be willing to let this person have complete control over my future on this project.

I really wish I had a good way to keep an eye on this person.

I would be comfortable giving this person a task or problem that was critical to me, even if I could not monitor their actions.

Perceived Follow-through (Zolin et al, 2001)

To what extent has this team member followed through on work commitments?

To what extent has this team member complete work commitments on time?

To what extent has this team member failed to follow-through on work commitments?

To what extent has this team member NOT completed work commitments on time?

To what extent is this person flexible and accommodating when it comes to requests for changes?

Perceived Trustee's work process

To what extent does this person provide timely and relevant information?

To what extent does this person find practical solutions to problems?

To what extent does this person make creative suggestions?

Perceived Trustworthiness (Mayer And Davis 1999)

This person is very capable of performing his/her job.

This person is known to be successful at things he/she tries to do.

This person has much knowledge about the work that needs to be done.

I feel very confident about this person's skills.

This person is well qualified for his/her role or function in the team.

This person is very concerned about my welfare.

My needs and desires are very important to this person.

This person would not knowingly do anything to hurt me.

This person will go out of his/her way to help me.

This team member has a strong sense of justice.

I have never had to wonder whether this team member will stick to his/her word.

This team member tries hard to be fair in dealings with others.

This team member 's actions and behaviors are not very consistent.

I like this team member 's values.

Sound principles seem to guide this team member 's behavior.

Excessive Checking (Zolin et al, 2001)

To what extent do you look to make sure this team member has not forgotten anything?

To what extent do you review this person's work to make sure this team member has not made any mistakes?

To what extent do you make sure this team member is not having problems?

To what extent do you check to see if this team member completed her/his commitments?

To what extent do you compare the work of this team member to others to evaluate their contribution to the group?

To what extent do you verify this team member's progress on the deliverables s/he promised?