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A Mediated Interaction Approach to Study the Role of Media Use in Team Interaction

By

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A MEDIATED INTERACTION APPROACH TO STUDY THE ROLE OF MEDIA USE IN TEAM INTERACTION

A DISSERTATION
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FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

Kathleen McKinney Liston

SEPTEMBER 2009

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

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I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

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(Diane Bailey)

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

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(John Kunz)

I certify that I have read this dissertation and that, in my opinion, it is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy.

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(Terry Winograd)

Approved for the Stanford University Committee on Graduate Studies.

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ABSTRACT

Do differences in how teams use media relate to differences in how teams interact? Does media use play a role in meeting synergy or breakdowns? This dissertation explores these questions in the context of Architecture, Engineering, and Construction (AEC) project meetings, using an approach that I developed, called Mediated Interaction Approach (MIA). My observations of over 100 project meetings showed that "good" and "bad" patterns of mediated interaction recur in meeting practice. The observations also showed that each meeting is unique, but made up of hundreds of interactions and patterns of interaction that repeat themselves in a meeting and from meeting to meeting. However, practitioners, media designers, and researchers lack methods and metrics to discern, describe, assess, and compare different patterns of mediated interaction. Consequently, practitioners and media designers rely on intuition or anecdotal evidence to make changes to meeting practice or meeting media. Developing such methods requires analyzing the relationship between media use and team interaction at a micro-level to identify and abstract patterns of mediated interaction that practitioners and media designers can use as a resource to improve meeting practice and meeting media.

Prior approaches examining aspects of the relationship between team interaction and media use miss key aspects of this dynamic, fall short of operationalizing team interaction or media use concepts, or are ill-suited for the meeting context. Existing models of team interaction conceptualize interaction as multi-purpose and analyzable with respect to three key processes—communication, reaction, and action—and these processes make contributions to project goals, to the meeting process (and its goals), and to interpersonal interactions. Existing studies operationalize at most two aspects of team interaction, e.g., communication and action, and address typically just one level of analysis, i.e., in relation to project goals, the meeting process, or interpersonal interactions. Thus, existing models and constructs are idealistic and unidimensional and do not capture the multi-purpose and multi-level nature of meeting interaction. Additionally, prior approaches operationalize team interaction and media use constructs that are task-, study-, or media- specific and are ill-suited for ad-hoc meetings that typically involve multiple tasks and multiple media. These studies limit their examination to feature-specific aspects of media use as opposed to general aspects of use, such as frequency and accessibility, level of interactivity, and instrumental purpose of media. This makes it difficult to compare patterns of media use involving multiple media. Finally, existing approaches miss the temporal aspect of meeting interaction and often rely on post-process data rather than observations. This makes it difficult to identify different patterns of mediated interaction that emerge and recur in meetings.

I developed MIA to address these shortcomings by observing over 100 AEC project meetings over a ten-year period and by analyzing 5,000 meeting interactions. MIA makes two key assumptions. First, the meeting process is analyzable as a set of discrete meeting interactions, each of which is analyzable from two distinct vantage points: how teams interact and how teams use media. Second, each meeting interaction

is analyzable relative to a standard of performance, regardless of task(s), that accounts for the multi-purpose and multi-level nature of teams. MIA comprises the following four contributions:

(a) A model of the meeting interaction process, the Mediated Interaction Model (MIM), that integrates and builds on prior models of interaction and media use, applies to multi-task and multiple media contexts, and conceptualizes the meeting interaction as four interdependent processes: communication, reaction, action, and media use that make contributions to the project, meeting process, and interpersonal interactions.

(b) A Mediated Interaction Analytic (MIA) scheme to operationalize the MIM concepts by interpreting and coding video-recorded meeting interactions.

(c) An Interaction Spectra Method to operationalize and visualize the multi-categorical, temporal concepts of team interaction and media use as a spectrum: a) the *Richness of Interaction* spectrum, representing the range of interaction from breakdown to status quo to synergy and the extent to which teams achieve synergy and b) the *Richness of Media Use* spectrum (RMU), representing the range of media use from no use to rich use and the extent to which teams interact and engage with media use in the meeting interaction.

(d) The MIA Relational Spectra Method to describe patterns of mediated interaction and the process of how teams use media in relation to the process of how teams interact.

Findings from MIA show that it is not the task or media that matter, but the interaction and media use. Teams achieved synergy performing a range of tasks using a range of media. Teams that make media part of the team interaction, i.e., involve media in key aspects of team interaction, experience more synergy. Teams that enact a less rich role for media, i.e., infrequent use of media and minimal physical interaction with media, are more likely to maintain status quo and experience intermittent breakdowns. The findings suggest a mutually dependent symbiotic relationship between media use and team interaction in AEC meetings. MIA describes but does not yet explain the differences in meeting interaction and is a step towards developing normative models of media use and team interaction in natural contexts.

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I am grateful for the support, constructive advice, and encouragement from my principal advisor, Martin Fischer. Martin expects and demands the best from his students and I strived to live up to those expectations. I am a visual thinker and I prefer producing visual figures to writing. Martin astutely suggested I put everything into pictures and figures and write from these figures. Consequently, this thesis is heavy on diagrams, pictures, and figures. Martin gave me countless opportunities to work with industry and the freedom to pursue those opportunities, starting with work at Autodesk and at Walt Disney Imagineering. These opportunities at Stanford and elsewhere contributed tremendously to my research and professional career.

I am indebted and truly thankful to John Kunz who inspired this intellectual journey in 1995 and encouraged me to pursue the PhD. John provided ongoing encouragement and politely demanded adherence to engineering methods advocated at the Center for Integrated Facility Engineering. Most importantly, John listened and reminded me to keep the "big idea" and "so what?" at the forefront of this process.

Terry Winograd inspired my interest in examining the human-computer interaction aspects of engineering work. I was fortunate to work with him, Pat Hanrahan, and Armando Fox, and an incredible group of talented students, including Brad Johansen on the i-Room project from 1999 to 2002. Participation in Terry's research group meetings broadened my view of engineering research, the processes of prototyping and testing, and developing media environments that teams can use.

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(a) (b)

Figure 1-1: Is team interaction shaped by the media environment? Snapshots of (a) traditional paper-based and (b) new digital-based media environments in architecture, engineering, and construction meeting practice.

Chapter 1: Introduction

Ten years ago, I experienced firsthand the differences in two meeting media environments. I sat in two back-to-back project meetings with the same multi-disciplinary team. The first meeting took place in a virtual-reality media space similar to that shown in Figure 1-1(b). The team collectively identified and solved multiple project issues. The second meeting took place in a traditional conference room with only paper media available to the project team similar to the one shown in Figure 1-1(a). The team spent most of the time clarifying issues and failed to solve any problems. I wondered how the same team could perform so differently in two different settings. Did the media environment explain the differences in team interaction? Do different patterns of media use positively or negatively affect team interaction and do different patterns of team interaction affect media use? I observed differences in how they communicated, reacted to one another, and acted on issues, yet constructs that practitioners or researchers use, such as productivity and performance, did not adequately explain the range of interaction I observed, or the rhythm and pace of the interactions. Exploring the relationship between team interaction and media use would require delving into the meeting dynamics, at a micro-level of analysis, and examining to what extent media use plays a role in key aspects of team interaction, and developing a standard of comparison that applies broadly to a range of team interaction and media use.

This dissertation explores these questions using an approach that I developed, called Mediated Interaction Approach (MIA) that analyzes, describes, and compares the dynamic relationship between team behavior and media use. This introductory chapter summarizes the research and development of this approach, following the steps in the "research horseshoe" process (Appendix A) (Fischer 2006). The chapter begins with the practical motivation for the research, including Case Examples, followed by an overview of the research: its theoretical point of departure, research questions, contributions, and methodology. The chapter describes four excerpts from architecture, engineering, and construction (AEC) project meetings representing the range of media use and team behavior that I observed. These examples act as case references throughout the dissertation.

1.1 Motivation: Differences in Patterns of Media Use and Interaction

The experiences on that AEC project ten years ago represented a significant shift in my research perspective—from a technologist to a social scientist—and research scope—from the desktop to the meeting context. My project role involved the design, development, and implementation of 4D tools (3D plus time) to improve project planning (McKinney and Fischer 1998; Schwegler et al. 2000). A key part of this process was observing practitioners using a prototype 4D tool in project meetings to collect user feedback, measure benefits of the tool relative to project goals, and improve the design and effectiveness of the 4D tool. I observed meetings daily, involving a range of media, from meetings with multiple forms of media to meetings with no media. These daily meeting observations provided a rare opportunity to compare and contrast the use of media and its effects on team interaction. I interpreted the meeting interaction through a "technologist" lens and attributed differences in team interaction—how participants communicated, identified, and solved problems, reacted to one another—to differences in the type of media the teams used. I assumed that teams using digital media performed better than those not using digital media or using paper media. The observation of productive, satisfying paper-based meetings and unproductive, unsatisfying digital-based meetings proved my assumptions wrong. Over time, I gradually shifted my attention away from examining the features of a single medium to examining the relationship between how teams used multiple media and how teams interacted. That is, I focused on the *process* of using multiple media, e.g., paper, digital and mixed-media. By doing so, I broadened my analysis to identify patterns of media use and the relationship between those patterns to patterns of team interaction. The engineering methods I was accustomed to, however, were insufficient to explore this dynamic. I gradually shifted towards a social science perspective of studying meeting interaction.

These early experiences as media designer, practitioner, and researcher acted as motivation for this study. On one hand, the positive interaction and effective media use I observed set a standard for what meetings could be and how media could play a role in improving meetings. On the other hand, as I delved into studying meeting interaction I faced multiple challenges. Meeting interaction does not easily lend itself to scientific study. There are multiple variables to examine and multiple possible perspectives of analysis. Most constructs or metrics that researchers or practitioners use to study meeting interaction are inadequate and rely on self-reported data or idealistic notions of meeting performance. The multiple media context makes it difficult to assess the benefits of a single medium relative to other media. The following section uses examples of interaction to elaborate these challenges and the practical motivation to examine meeting interaction more closely.

1.1.1 Motivating Case Examples: Differences in Meeting Interaction

I observed over one hundred hours of project meetings, ranging from early conceptual design to schedule review meetings. The following are four detailed excerpts of meeting interaction from four of those meetings that illustrate different patterns of team interaction and media use that recurred in these

observations. Many other patterns recurred, but I use these for illustrative purposes. For each Case Example, I examine the meeting interaction from two distinct vantage points:

(a) *How the team interacts:* The "team interaction" perspective examines the meeting interaction through a "multi-purpose" lens and includes social and functional purposes: Is the team focusing on project-related issues? Is the team communicating or exchanging project information? Is the team identifying, solving, or evaluating project issues? Are participants reacting positively or negatively to one another?

(b) *How the team uses media*: The "media use" perspective examines the meeting interaction in terms of if, how often, and how teams use and interact with any media: Is the team using media? If so, what kind of media are the team using? Are the media accessible to some or all meeting participants? How are they interacting with the media? And for what purpose?

As you read the examples, pay attention to several aspects of the meeting interaction at different levels of analysis. From a project-level perspective, consider whether the interaction supports or contributes to achieving project goals or maintains or improves team cohesion. From a process-level perspective, consider whether the team facilitates or manages the meeting process. From an interaction-level perspective, consider how the team members relate to one another, exchange information, react to one another, and maintain or continue the flow of communication. At each level of analysis, consider whether media use supports, impedes, or in some cases, plays no role in those activities. Note that focusing on one level of analysis misses key aspects of the meeting interaction. This is important since existing approaches focus on at most two of these levels of analysis (Chapter 2). I discuss in Chapter 2 the rationale for examining interaction at these three levels and use these examples for reference. Finally, compare and contrast the interactions and consider which interaction you would interpret as typical, ideal, or atypical? Note the challenges of readily interpreting these differences or making such comparisons.

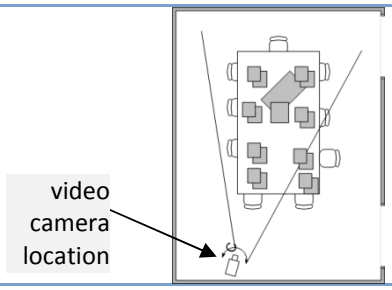
The narrative analysis accompanying each Case Example synthesizes findings from this research and uses terms developed in prior studies and this research. Throughout the dissertation, I present alternative methods to describing and comparing these examples including quantitative and visualization methods. Each Case Example lists the type of meeting, the phase during which the meeting took place, the number of participants, the media available in the meeting, the duration of the excerpt, and a 2D layout of the meeting with the location of the video camera. Chapter 3 discusses the transcript notation in detail. Italicized, double parentheses enclose non-verbal meeting interaction.

1.1.2 Case Example A: Status Quo Team Interaction and Low Media Use

Meeting Interaction A is an example of "status quo" interaction—periods of time when the team communicates and takes stock of the issues, clarifies and responds to one another, and expresses no emotion—and low media use—periods of infrequent use and use of private media (media that are only available to a single meeting participant) to support team communication. Throughout the one-hour meeting, the team repeats this status quo pattern as the team reviews the project schedule and discusses project issues. The team rarely uses any media, often shifting their attention from each other to the various documents in front of them. In this excerpt and throughout the meeting, the team identifies project issues, but does not resolve them, and commits to addressing issues offline.

Meeting Interaction A: An excerpt of a paper-based meeting describing a typical "status quo" pattern of team interaction with little to no use of media.

Meeting Type	Construction Review
Phase	Construction
Number of Participants	8
Media	Personal copies of item log, schedule, set of drawings
Excerpt Duration	1 minute

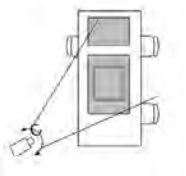


C:	So it's our understanding that the revision to change order 42 and once you and X look through this umm….knee brace issue. Those were the only 2 items that are OSHPOD change orders that correct the brace frame steel issues.		The participants look at media, privately, but rely on personal knowledge to communicate.
B:	No. No.		
C:	Are there any other ones that you need to find out the status?		The participants continue to discuss issues without using shared media referring periodically to private documents in front of them.
B:	No, there are change orders, because what we did down below the C-line on the ground level the spacer plate we're going to a 3" so we miss the #12 bars…the vertical #12 bars that we can't cut out so that we're out beyond it.		
C:	Was that taken care of in change order 42?		The team continues to try to clarify the issue but cannot agree on resolution or confirm the information.
H:	It's going to.		
B:	It's not though.		
H:	Change order 42 is already approved.		
C:	I know.		
H:	So we have to issue a new change order.		
C:	Okay.		
H:	Rescinding 42 and I think it's going to be 44 is what it is.		

1.1.3 Case Example B: Synergistic Team Interaction and Shared Use of Paper-Based Media

Meeting Interaction B describes a "synergistic" pattern of team interaction—when the team focuses, solves problems, reacts positively to one another—and "rich media use"—when the team uses shared media interactively to generate project information. The 40-second meeting interaction is from a one-day charrette meeting to design concepts for a new downtown community center. The meeting context is a table with overhead images of a project site and tracing paper to sketch potential ideas for the new downtown community center. The team members take turns drawing ideas and taking input from various meeting participants. The team actively uses the media to generate and communicate multiple ideas, using the media as a workspace to generate ideas and the media as a tool for comparing ideas. At the end of the meeting, the team has three potential design options.

Meeting Interaction B: A "synergistic" pattern of team interaction and "rich" media use.

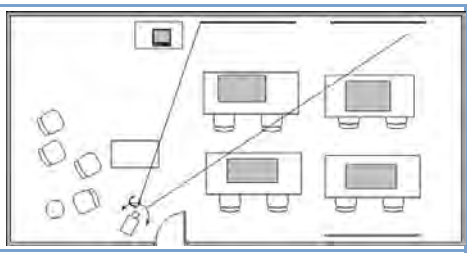
Meeting Type	Conceptual Design	
Phase	Concept	
Number of Participants	12	
Media	Paper drawings, images, overlays	
Excerpt Duration	40 seconds, early in the meeting	
G: I think putting parking here and balance that and get up... J: Some sort of water...because this is such a large area *((pointing to paper))*		The team works around a shared workspace, pointing to the media and generating ideas.
J: Water flowing over the side... B: Sound...		Individuals use gestures to communicate various design alternatives, often referring to the drawings collectively shared by all participants.
G: Sound…reflecting off the C: light.. That's a great idea. How about ponds to reflect the light underneath? *((pointing))*		The team verbally describes design concepts and builds on each other's ideas, continually referencing the concept drawings.
G: …gondola crushing... A: So we're talking about… *((draws something))* G: I like that!		After a few seconds of discussing a design idea a team member draws the concept and another team member reacts positively.

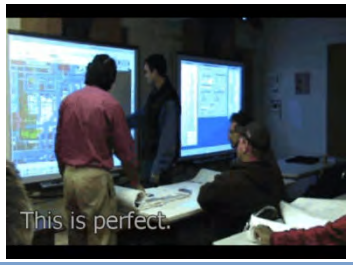
1.1.4 Case Example C: Team Interaction Breakdown and Medium Media Use

Meeting Interaction C is an example of a "breakdown", a period of time when the participants stop communicating and react negatively towards one another and medium media use—moving between shared and semi-shared media use to address project issues. This example is from a Mechanical, Electrical, and Plumbing (MEP) coordination meeting. The meeting context is a room with two digital SMART boards. One shows a 3D digital model of the project. Several meeting participants arrive late to the meeting while others leave throughout to attend to other project issues. In front of some participants are paper project drawings. The team attempts to address conflicts, but cannot agree on dimensions, with some members referring to the paper drawings and others to the digital model. While these team members focus on coordination issues, there are multiple periods of sidebar discussions between meeting participants. There is some expression of frustration. The team fails to address the main conflict issue. The example begins 25 minutes into the meeting and a period of 2.5 minutes of digression follows this interaction. Over a period of 80 seconds, the team moves from a period of interacting to some synergy then to a breakdown.

Meeting Interaction C: A mixed-media meeting illustrating a "breakdown" and "medium" media use.

Meeting Type	MEP coordination
Phase	Construction
Number of Participants	13
Media	Digital model, 2 digital whiteboards, paper drawings
Excerpt duration	50 seconds

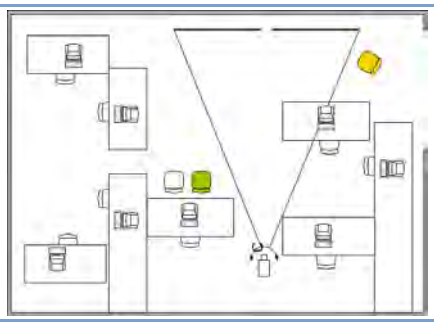
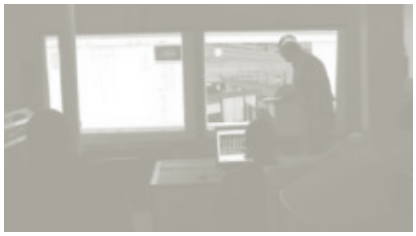


A:	You think the 10' wall is coincident with that wall on the mezzanine catwalk. That's ***what*** you are telling me?		The team is trying to coordinate a potential conflict between a catwalk, piping, and structural elements. One of the team members moves the model view to the location of the conflict.
C:	...that's what the drawing says. Yes.		
A:	I don't believe that is true. Because you don't have a mezzanine drawing to show me.		"C" chooses to look at the drawing instead of the model to locate the conflict. The rest of the team members do not have access to the drawing. "A" tries to tell "C" that the drawing does not show the catwalk.
C:	I have a reflected ceiling pattern that says...		
A:	But you don't have the catwalk above it.		
	((looking at drawing))		
A:	This is perfect.		"A" is frustrated and re-asks the original question. "C" responds, but with no commitment and returns to looking at the drawings. "A" walks away and the next two minutes involve a series of sidebar discussions until the team regroups and moves onto another issue.
A:	Okay. So if that's not true, can I make 10'5 ceiling coincident with that wall?		
C:	Sure.		
	((looking at drawings))		
	((various conversations, looking at drawings, whiteboard))		

1.1.5 Case Example D: Synergistic, Rich Media Use

Meeting Interaction D is an example of "synergistic" team interaction and "rich" media use. The meeting is a MEP coordination meeting (similar to Meeting Interaction C). The meeting context is a room with two whiteboard displays in front. One shows a view of a digital 3D model and the other a summary of views showing a list of conflicts. The team reviews each issue and proposes solutions to address conflicts. A designated team member makes notes once an issue is resolved. The team repeats this process, resolving all conflicts, identifying and resolving new ones. The team focuses on the conceptual design tasks, produces design alternatives, and the team members positively react to one another. The meeting interaction takes place 15 minutes into the meeting.

Meeting Interaction D: Digital-based meeting interaction illustrating "synergistic" team interaction and "rich" media use.

Meeting Type	Construction Review		
Phase	Construction		
Number of Participants	12		
Media	Personal copies of item log, schedule, set of drawings		
Excerpt duration	80 seconds, 15 minutes into the meeting		
	((silence as the team views and walks through a 3D model of the building floor))		The team reviews the model silently as a model manager coordinates the "fly through" of the digital model. The team identifies an issue. The team jokes about it.
A:	Mike, what do you got there?		
B:	Looks like a 1" pipe.		
	((laughter))		
A:	Right. Just go in under the cable tray in the elbow?		"A" suggests an alternative and "B" agrees. They quickly suggest a solution to the conflict.
B:	Yep.		
A:	This can simply be dropped back here.		
B:	Yep.		
A:	Okay.		
A:	"H", go ahead and show it elbowed off of here.		Once the team agrees on a solution, "H", a person assigned the role to mark up solutions, marks up the model per "A"'s instructions.
A:	Okay.		
D:	Turn right here? *((pointing to model))*		
A:	Turn right there turn right here.		
A:	This is going to be moved down to here. Draw a line right across here. *((member marks-up on the model))*		
A:	Just draw a line right across there. *((member makes additional mark-ups on the digital model))*		

1.1.6 Challenges to Describing and Comparing Natural Meeting Interaction

These examples illustrate two important aspects of interaction. First, no single perspective adequately conveys all of its nuances. Second, interaction changes moment-to-moment with respect to both how teams interact and how they use media. These examples illustrate four possible combinations of interaction and media use. Within each of these meetings, other patterns of mediated interaction occur, from periods of status quo and rich use to periods of breakdowns and rich use. Each example represents a one-minute portion of the meeting. In some cases media use varied within the example (Example C), whereas in other examples media use did not change (Example A). In some cases, the interaction changes dramatically from one moment to another, as in Example C. By delving into the moment-to-moment interaction these changes are observable.

These examples also illustrate characteristics of meeting interaction that pose challenges for examining it: the team make-up, the ad-hoc nature of meeting activity, intangible outputs, and use of multiple media.

AEC project ***teams are multi-disciplinary, cross-organizational, and their make-up is constantly changing.*** A typical $10 million dollar AEC project involves over 400 organizations, including architects, engineers, builders, laborers, specialty consultants, etc., and over 800 individuals (Hendrickson 1998). The projects require cognitive and physical input from multiple individuals and organizations with domain-specific expertise and experience. I rarely observed two meetings with the same group of professionals even when I followed a project for several weeks or months. Additionally, the demands of project work lead to entry and exit of meeting participants during a single meeting (Example C). This makes it difficult to account for the effect of individual-level, such as personality or expertise, or group-level factors, such as history or structure, on team interaction.

Meeting interaction is ill-defined and ad-hoc and involves tasks that often span multiple meetings. AEC projects are complex, intensive efforts to plan, design, and build a physical artifact such as a building, road, or campus. AEC teams tackle ill-defined, ill-structured, and messy or fuzzy problems with no right or wrong answers and multiple potential solutions (Simon 1973; Ackoff 1974; Mintzberg et al. 1976). In the excerpts, the interaction moves from issue to issue, involving a variety of tasks and processes, from making decisions (Example D), clarifying issues (Example B and C), identifying and solving issues (Example D), generating alternatives (Example C and D), addressing conflicts (Example C), and socializing (Example A and D). Most meetings I observed did not use a formal agenda, and teams often did not define specific meeting tasks a priori. Many meeting tasks cover multiple meetings. The changing ad-hoc interaction practices make it difficult to compare meetings.

Many researchers would explain the differences in the Case Examples as a function of task, but I argue that regardless of the type of task(s) project teams perform in the meeting context teams should achieve some level of performance. If practitioners and researchers rely on methods that describe or assess meeting process as a function of task(s), then it will be difficult to apply to meetings given their ad-hoc nature. Furthermore, if we make the assumption that performance is not a function of task, but other

characteristics of the process, then it is possible to identify patterns of meeting interaction associated with different levels of performance and identify the characteristics of the team interaction. That is, even though, Examples B and D are examples of teams performing different tasks, both are examples of high-performing teams. Identifying the key aspects of team interaction that these examples share and is a first step to developing a set of normative process characteristics. Similarly, the teams in Examples C and D are both performing MEP coordination, and identifying how they differ will also lead to identifying process characteristics that are more or less desirable. Thus, I argue that regardless of what teams are doing in a meeting, it is possible to apply some standard of assessment to compare and improve meeting interaction.

Meeting output is not discrete or readily tangible. Most projects occur over weeks, months, and years, and project artifacts—designs and physical products—are in an ongoing state of transformation and realization. Consequently, meeting output usually is not a physical, tangible product, sketch, or model. The output is a set of changes to the design, set of issues the team needs to resolve, and tasks to perform. This makes it difficult to assess meeting interaction using constructs such as productivity or effectiveness that are dependent on tangible outputs and well-defined goals.

Teams use multiple media including drawings, surveys, construction schedules, engineering and jurisdictional codes, and programmatic requirements. Different disciplines and organizations use different media for different purposes. Access to media and familiarity with media vary depending upon a participant's location in the meeting space and their familiarity with specific media. For example, in Example A, only a portion of the team can see the landscape and architectural drawings. Many approaches to study media use are media-specific and task-specific. This makes it difficult to isolate the interactions associated with a specific medium or to assess its benefits relative to other media. Practitioners face similar challenges with respect to implementing media and changes to meeting processes due to the different skills, domain expertise, and media experience within the project team.

1.1.7 Why Study Meeting Interaction?

Meetings play a vital role in construction practice and their effectiveness impacts everyday activity on construction projects. Meetings play a critical role throughout projects as a forum to bring together project team members to develop a shared understanding, address project issues, and reach consensus (Rosenman and Gero 1998; Foley and Macmillan 2005). A typical project may involve hundreds or thousands of meetings addressing a multitude of issues. Meetings cover a broad range of topics and issues, with some issues resolved in a few minutes to others spanning multiple meetings. Project teams spend a significant portion of the week in meetings. Various studies, from other industries, report that professionals spend 20-70% of the workweek in scheduled and informal meetings (Panko 1992; Ritz 1994; Romano and Nunamaker 2001; Hudson et al. 2002; González and Mark 2004), with managers spending more time than other team members do. AEC projects typically have three to four weekly face-to-face scheduled meetings, such as project review and coordinating meetings. Several studies cite the importance of face-to-face meetings and co-location of teams as a success factor in team performance (Hinds and Weisband; Garcia et al. 2004; Baiden et al. 2006).

There is a general perception that meetings are a waste of time and unproductive, but there is no evidence or data to support or contradict this assertion (Schrage 2000; Garcia et al. 2003). Additionally, there is a general lack of attention to meetings in the practice or research communities. AEC organizations spend time monitoring, measuring, and improving field productivity or office productivity, but little time assessing meeting performance. AEC management or professional handbooks rarely address the topic of meeting practice and practitioners generally accept meeting practice and use of meeting media as modus operandi. The literature contains a handful of studies devoted to the study of meeting practice in AEC (Garcia et al. 2003; Foley and Macmillan 2005) and a sampling more to meetings in collaborative project practice (Grohowski et al. 1990; Carter et al. 1992; Olson et al. 1992; Pollard and Hayne 2002; Beck 2008). It is no surprise that the constructs and terms that practitioners and researchers use, such as "unproductive", "wasteful", "effective", "bad", and "good", to describe meetings are vague, idealistic, and fail to capture the richness of meeting interaction. These terms and conceptualizations focus on the functional, goal-oriented aspects of meetings, miss the communicative and social aspects of meetings, and altogether ignore the role of media in the process.

I contend that meetings are not *that* bad or busy professionals would replace them. What is bad are the idealistic notions of what meetings should be, the relegated role of media, and the constructs researchers and practitioners use to describe and compare team interaction and media use. In the absence of science of meeting practice or media use or normative models, practitioners, media designers, and researchers either ignore meetings as a subject of study or rely on intuition to guide any effort to improve practice or meeting media. Normative models of meetings, though, require understanding at a micro-level, the key aspects of the meeting process and the dynamics between how teams interact and how teams use media.

1.2 Intuition

Like buildings, each meeting is unique. Professionals use the same bricks and patterns of arranging bricks to build good and poor buildings, and professionals use interactions and patterns of interactions to address unique project-specific issues more or less synergistically in meetings. However, research has, thus far, not developed a formal method to discern the "bricks" of meetings, i.e., to understand how different patterns of mediated interactions shape the meeting process and outcome. Needed is an approach to systematically observe, interpret, and analyze meeting interaction from two distinct foci of analysis: (a) how teams interact and (b) how teams use media. Media designers, practitioners, and researchers can use this approach to identify patterns of "mediated interaction" and use these patterns as resources to improve meeting media, meeting practice, and models of meeting interaction. The approach should:

(a) use observation-based data as opposed to self-reported, pre-process, or post-process data to describe the process of interaction and the moment-to-moment changes in team behavior and media use;

(b) describe team interaction and media use from multiple perspectives and at multiple levels of analysis;

(c) conceptualize team interaction as ad-hoc, dynamic and observable through the team acting as functional unit (Cannon-Bowers et al. 1996).
(d) conceptualize media use as a process of using multiple media in a physical context.
(e) Establish a standard for comparison that is realistic and not idealistic.

Developing an approach using these criteria is a first step towards understanding the relationship between team interaction and media use in natural contexts versus lab-based contexts and towards developing normative models of meeting interaction.

1.3 Point of Departure

How teams interact or use media is the focus of multiple disciplines including Organization and Information Science, Social Psychology, Human-Computer Interaction, and Design Research. These studies include a multitude of theories, concepts, constructs, and methods to study interaction. The following paragraphs summarize the influence of four fundamental concepts from these studies on my approach to describing and comparing meeting interaction: (a) systematic methods to observe and analyze interaction processes, (b) the multi-purpose perspective of group interaction, (c) process gains and losses, and (d) an emergent perspective of media use in organizational contexts. I discuss the shortcomings of these approaches relative to the criteria in the previous section. I begin by clarifying several terms—concept, construct, media, media use, team, team interaction—to avoid misinterpretation or confusion, since many of these terms are widely used in the literature with multiple definitions. Appendix B contains a full glossary of terms and acronyms used in this dissertation.

1.3.1 Terminology and Scope

I use the conceptual terms *team interaction* and *media use* to distinguish the two analytic foci in this research (Jordan and Henderson 1995, p. 57). I chose these terms carefully as I did all of the terms in this dissertation. Bear in mind that this dissertation operationalizes these high-level concepts, first as a set of process concepts (Chapter 2 and 3) and related constructs (Chapter 5), and then using operational definitions (Chapter 5) (Figure 1-7). A concept is an abstract idea, and I distinguish *constructs* from concept using Black's definition:

> **construct (n):** ways of elaborating upon an abstract concept (created or enhanced) in order to facilitate making observations that will support the theory under investigation (p. 36, Black 1999).

Everyone has a meaning of the concept of interaction, for example, but studies develop constructs to investigate more specific aspects of interaction. Corbin and Strauss (1990) use concepts as the basic unit of analysis or the labels to describe their observations and aggregate concepts into categories. I use the term *code* and *label* to refer to the naming of observational phenomena. For example, the Case Examples explore the concept of team interaction and use the concepts of "synergy", "status quo", and "breakdown" to describe differences in team interaction. The examples, however, do not use a specific construct to relate these concepts. Chapter 5 discusses the construct, Richness of Interaction, which relates these concepts and provides a single measure to describe each meeting interaction or set of meeting interactions. *Operational*

definitions are rulers or instruments that produce acceptable ways of measuring constructs (p. 36, Black 1999). Operational definitions concretize concepts and provide researchers with examples of how to study and analyze a concept. The absence of operational definitions, particularly in theoretical research, leads to misinterpretation of the concept. For example, Chapter 5 presents operational definitions to calculate the Richness of Interaction for each of the Case Examples. I use the terms *concept*, c*onstruct*, and *operational definition* to review and assess prior approaches since studies vary with respect to the systemization and formalization of operational definitions.

One of the challenges in this research was selecting and defining labels to describe the various man-made objects in meetings, such as sketches, models, drawings, digital models, documents, photos, maps, and digital displays, that teams use to support and perform a variety of meeting tasks. AEC project teams use a variety of objects to communicate and capture project information. These objects vary in form, physicality, interactivity, and information content. Researchers commonly use the term *artifact* to describe these objects (Bucciarelli 1988; Orlikowski 1995; Suchman 2000; Bechky 2003; Schmidt and Wagner 2004; Tory et al. 2008). The term artifact, though, carries a conceptualization of a static object that is unchangeable in content or form. I found it difficult to label objects such as a digital model or a multi-display environment or even sketches as artifact since teams interact with, change, and annotate these objects and their informational content. In organizational and computer-related studies, the term *technology* is commonly used (Barley 1986; Losado et al. 1990; Nunamaker et al. 1991; Poole et al. 1991; DeSanctis and Poole 1994; Heath et al. 2000). This label is inadequate to describe objects such as sketches or physical models. Additional terms used to refer to these objects are visual communication devices, boundary objects, or group decision support systems (Jarvenpaa et al. 1988; Watson et al. 1988; Zigurs et al. 1988; Henderson 1991; Hendry 2004). I selected the term media to refer to these objects because its literal definition supports the multiple functions of these objects and does not limit its application to digital or physical objects:

> **medium (n.)**: an intervening agency, means, or instrument by which something is conveyed or accomplished.

I conceptualize media in multiple ways: media as tool, media as artifact, and media as workspace, and these conceptualizations sufficiently categorize the objects that teams interact with in the meeting context. This conceptualization also supports the multiple ways in which teams interact with those objects. For example, in Case Example B, the team uses the media as a workspace to draw ideas, as a medium to communicate previous ideas, as an artifact to store and reflect upon design ideas, and as a tool to overlay ideas. *Media use* refers to the conceptualization of the process of interacting with the various media—how often teams use media, how many media they use and what type of media, how the teams physically interact with the media, and for what purpose. I elaborate upon this conceptualization of media use throughout this dissertation.

Throughout the dissertation, I use *team* and *project team* interchangeably to distinguish it from a generic group (Guzzo and Dickson 1996). Team is a specific type of group and there are different types of teams. AEC project teams fit the definitions of *project* team found in the literature:

> **team**, **project team** (n.): a multi-disciplinary group of three or more individuals who are interdependent in their tasks, interact intensively, for a time-limited period, committed to provide a 'built' product, plan, or service (Tannenbaum et al. 1992; Katzenback and smith 1993; Cohen and Bailey 1997; Devine et al. 1999).

It is these characteristics of teams, as noted earlier, that pose challenges to study team interaction in the natural meeting context. *Team interaction* refers to how teams act and react in relation to the *systems,* e.g., project, team, meeting, within which they interact (McGrath 1991). I use the terms *team interaction*, *team behavior, and team activity* interchangeably throughout the dissertation as do Bales et al. (1951), Allwood (1977), Adrianson and Hjelmquist (1991), and Moore et al. (2004). I use the term *meeting interaction* to refer to the interdependent behaviors of the team as observed through the individual and collective acts of team members and to which these two analytic foci apply. I use the term *mediated interaction* to refer to the collective set of team interaction behaviors and media use behaviors, i.e., the perspective of meeting interaction that views meeting interaction as the mutual processes of team interaction and media use.

1.3.2 Approaches to Describe, Analyze, and Compare Team Interaction

The seminal theories and models of team interaction assert that team interaction is multi-purpose and has social and functional purposes (Bales 1950; McGrath 1964; Steiner 1972; Hackman and Morris 1975). McGrath (1984) subsequently proposes a model of interaction that comprises three processes: communication, reaction, and action[1]. I build on this fundamental concept and conceptualize team interaction as the three interdependent processes of communication, reaction, and action and that at any moment the team is engaged in one or more of these processes. The Case Examples show that at times the teams are communicating and acting or at times reacting (Example C). These models offer a theoretical basis to break apart interaction into three processes, but the studies fail to operationalize these constructs.

These models of interaction, though, are ill-suited to study and describe meeting interaction due to their dependencies on tasks or reliance on tangible outcomes. As discussed in the previous section, meeting tasks are ill-defined and the outcomes are intangible. Thus, models of interaction that make these assertions, such as the seminal input-process-output model (IPO) (McGrath 1964; Hackman and Morris 1975) and IPO-based models are ill suited to study natural meeting interaction. Most researchers invoke a "black box" perspective of the IPO model and develop operational definitions that are study-, input-, or output-specific and do not directly measure the process. This makes it difficult to apply these findings or approaches to other domains or to the natural meeting process. McGrath's Time, Interaction, and Performance (TIP) theory (1991) elaborates upon this notion of multi-purpose interaction and asserts that

[1] McGrath uses the term "acquaintance process", but I use the term reaction; and McGrath uses the term task-oriented, but I use the term action (Section 2.2.2).

teams make contributions to multiple systems within which they interact such as the organization or the project. In this sense, teams are complex systems and analyzing their interaction requires multi-level analysis. My approach builds on these fundamental concepts by examining interaction relative to multiple purposes—communication, reaction, action—at multiple levels of analysis—project, meeting process, and interaction.

The IPO researchers and seminal research by Bales conceptualize interaction as a set of interdependent observable behaviors discretely analyzable from multiple perspectives (Bales 1950; Hackman and Morris 1975). McGrath (1991) formalizes this conceptualization in the TIP theory of group interaction. TIP asserts that at any point in time in interaction, a group has a purpose and takes its meaning from the context within which it occurs. McGrath further asserts that aggregation of these acts constitutes workflow patterns that support qualitative analysis of interaction. McGrath's theoretical work establishes a foundation for systematic analysis of interaction from multiple perspectives and identification of patterns of team interaction. McGrath's work or subsequent researchers fail to elaborate upon these concepts and define constructs that capture this conceptualization and the temporal aspects of meeting interaction. Instead, researchers invoke these conceptualizations by developing study-specific constructs and operational definitions that offer no standard for comparison or generality and reduce process dynamics to a single descriptive process measure. For example, concepts such as group performance and productivity have dozens of different operational definitions. These simple constructs tell us nothing about the meeting dynamics.

Steiner's conceptualization of interaction as process gains and losses comes closer to capturing process dynamics and relating process to a standard. Steiner's seminal theory of group productivity posits that group productivity is equal to "ideal" productivity minus process losses. Process losses include evaluation apprehension, domination, and information overload (Nunamaker et al. 1991; Alavi 1994; Fjermestad and Hiltz 1998). This conceptualization views the discrete interactions in terms of the nature of the tasks and resources utilized and examines them as "losses". This model offers a theoretical link to associate discrete interactions to contributions in terms of gains or losses to the multiple purposes of the teams. Hackman (1987) disagrees with Steiner's conceptualization of interaction as "losses" and proposes a normative model of team interaction that conceptualizes process synergies (gains) and losses. McGrath's TIP theory goes one step further and asserts that every interaction has meaning and makes a contribution to some system and purpose.

My approach builds on the concept of gains and losses as a means to describe interaction relative to a team's purpose and shares McGrath's view that every interaction makes some relative contribution to the project, process, or interpersonal interactions. Steiner, McGrath, and Hackman do not formally operationalize the concept of gains and losses and researchers that operationalize the concept do so using self-reported data (Nunamaker et al. 1991; Alavi 1994; Bolin and Neuman 2006) and do not examine process losses or gains from one set of interactions to another.

These conceptualizations provide the theoretical underpinning for my approach. A multitude of other studies influenced my approach. In particular, Workplace Studies and Design Research studies played a significant part in developing concepts and ways to examine meeting interaction. Workplace Studies use narratives to describe interaction in everyday organizational activity, but lack formal approaches to describe or compare their observations (Bermudez and King 2000; Heath et al. 2000; Suchman 2000). Design Researchers use formal frameworks but limit their study to a single perspective of analysis (Tang 1989; Minneman 1992; Milne 2005).

From these studies and review of the literature, I conceptualized the team interaction process as three interdependent processes of communication, action, and reaction and every meeting interaction is purposeful and potentially makes contributions to the project, meeting process, and interpersonal interactions. Figure 1-2 summarizes the contributions of prior studies to this conceptualization.

1.3.3 Approaches to Describe, Compare, and Analyze Media Use

Conceptualizations of media use range from macro-scale models of media in organizations to cognitive models of media use in Human-Computer Science and Cognitive Science. DeSanctis and Poole's Adaptive Structuration Theory (AST) and the related "emergent" conceptualizations extend the IPO framework to account for the role of media use in interaction (DeSanctis and Poole 1994; Maznevski and Chudoba 2000; Orlikowski 2000). AST conceptualizes interaction as a mutual interplay of media use and interaction observable through the structures in media, i.e., the features, capabilities, and spirit of the media and in structures organizations, i.e., the resources, procedures, and rules, and changes to those structures. DeSanctis and Poole operationalize AST constructs using a coding scheme to label meeting interactions. This study builds on the AST conceptualization of the relationship between media use and interaction:

> *"the two (technology and interaction) are continually intertwined. There is a recursive relationship between technology and action, each iteratively shaping the other. But if we are to understand precisely **how** technology structures can trigger organizational change, then we have to uncover the complexity of the technology-action relationship" (DeSanctis and Poole 1994, p. 125).*

AST was a distinct departure from prior models of group interaction since it includes the process of media use and examines the mutual effects of team interaction and media use. AST describes a complex, temporal relationship between team interaction and media use. I share DeSanctis and Poole's goal to uncover the complexity of the media use-team interaction relationship. Whereas DeSanctis and Poole focus on how features of a single new media trigger change to organizational structure, I focus on how differences in multiple media use relate to differences in how teams interact. By examining that relationship, I seek to identify patterns of mediated interaction as opposed to patterns of change and structure.

A multitude of media use related studies influenced specific concepts and constructs in my approach. These include Computer Supported Cooperative Work (CSCW) studies on meeting-specific media (Nunamaker et al. 1991) and HCI studies examining characteristics of interaction in natural settings (Suchman and Trigg 1992; Lebie et al. 1996; Dix et al. 1998). These studies lack formal models of media

use but like the Workplace and Design studies enlightened my perspective of media use and contributed to the formalization of concepts.

In summary, no single approach conceptualizes, operationalizes, and describes the dynamic process of mediated interaction. Existing approaches lack constructs that capture the temporal aspect of interaction and methods to convey the moment-to-moment differences in meeting interaction from both the team interaction and media use perspective. In the absence of such constructs or methods, practitioners, media designers, and researchers rely on idealistic or single-dimensional constructs, to assess and improve meeting practice and media. These approaches tell us whether the teams in the Case Examples are satisfied with the process, productive or unproductive, and whether they met project or process goals. We can only speculate as to whether media use played a role in those differences.

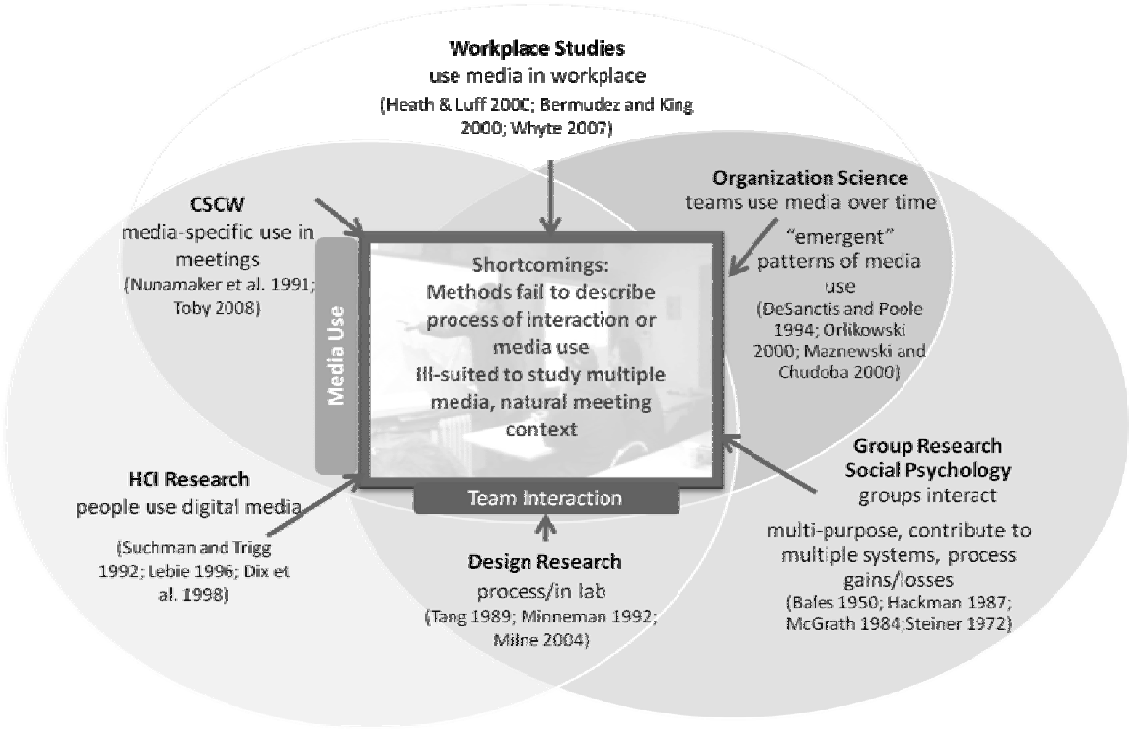


Figure 1-2: Summary of point of departure for this research. The research builds on and integrates research from multiple fields that look at how teams interact and use media. No single approach, however, captures and describes the process of interaction and its relationship to the process of media use.

1.4 Research Questions and Contributions

The goal of this dissertation is to explore the relationship between how teams interact and how teams use media such that practitioners, media designers, and researchers can use observation and analysis of meeting interaction to improve meeting practice and media. The main research question is:

(RQ) What role does media use play in how teams interact in AEC project meetings? What role do differences in team interaction play in media use?

I answer this question in four parts guided by the criteria established in Section 1.2, the shortcomings of prior approaches, and my observations of project meetings. The first challenge is conceptualizing the interaction process:

(RQ1) What is a model (conceptual and operationalized) of the meeting interaction process that relates the process of multi-purpose team interaction to the process of multiple media use and to the project, meeting process, and interpersonal interactions?

I answer this question with a Mediated Interaction Model (MIM) of meeting interaction (Figure 1-3). This model conceptualizes interaction as two interdependent processes: team interaction, comprising communication, reaction, and action processes, and media use, comprising the use, interacting, and purposing processes. These interaction processes are observable through the interpersonal behaviors of the meeting participants and each meeting interaction is analyzable with respect to each of these processes. Each meeting interaction has a purpose and makes contributions to the project, meeting process, or interpersonal interactions. MIM conceptualizes the moment-to-moment process gains and losses relative to previous interaction or subsequent interaction. Chapter 2 answers this question synthesizing prior models of interaction discussed in Chapter 2.

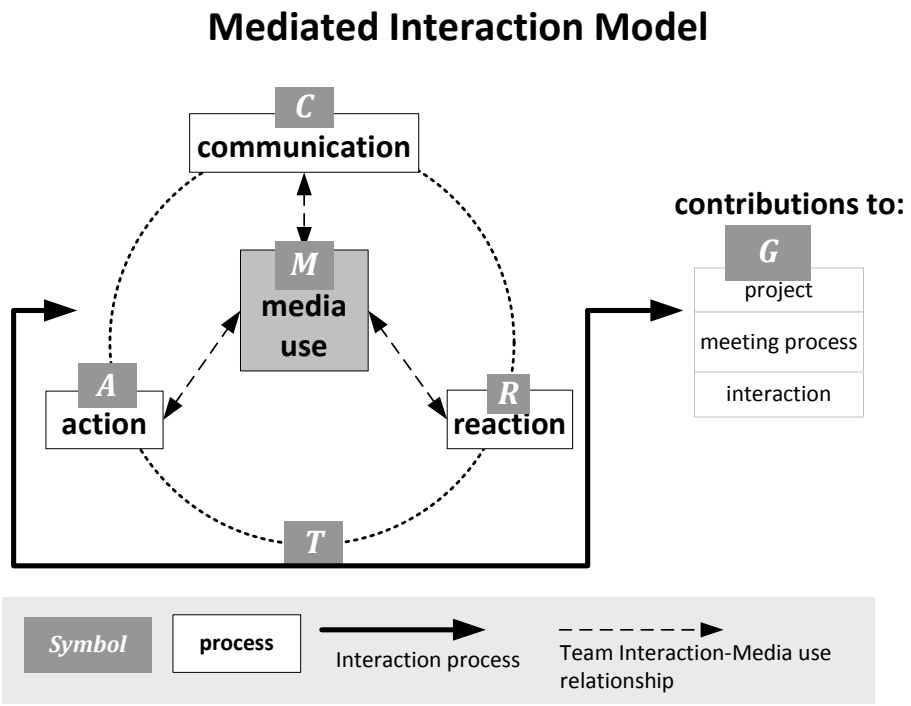


Figure 1-3: Mediated Interaction Model (MIM) of meeting interaction. This model conceptualizes and formalizes interaction (I) as four interdependent processes of team interaction (T) and media use (M) that make moment-to-moment contributions, G, to the project, meeting process, and interpersonal interaction. The team interaction process is made up of three processes: communication (C), reaction (R) and action (A). Chapters 2-6 elaborate this model.

The second question addresses the issue of operationalizing the concepts in MIM to apply this model to observations of meeting interaction:

(RQ2) How can the meeting interaction process be interpreted and analyzed to describe differences in how teams use media and how teams interact in video-recorded meeting interaction?

I answer this question in two parts. First, I elaborate the concepts in MIM through review of the literature. Second, I perform a comparative analysis of prior coding schemes that operationalize one or more of the MIM processes. The result is an ontology of team interaction and media use behaviors (Figure 1-4) that synthesizes prior concepts and a related Mediated Interaction Analytic (MIA) scheme **(**See Chapter 4, Figure 4-4**)**. Chapter 4 discusses the development and rationale of this coding scheme.

The next challenge is operationalizing the concepts of team interaction and media use:

(RQ3) How can the concepts in MIM be operationalized and visualized to describe and compare (a) the process of team interaction relative to the range of team interaction observed in AEC project meetings and (b) the process of media use relative to the range of media use observed in AEC project meetings?

I develop an Interaction Spectra Method (ISM) that operationalizes two multi-dimensional constructs as a spectrum of interaction and visualizes moment-to-moment changes in meeting interaction relative to this spectrum. Each richness construct represents a range of interaction along a spectrum with three "zones" of interaction:

(a) ***Richness of Interaction*** *spectrum* (Figure 1-5[a]): Conceptualizes interaction as a process ranging from breakdowns to synergies. The spectrum distinguishes between periods of time when the team is focused, looking forward, i.e., solving problems or generating alternatives, ideas, reacting positively to one another, and committing or resolving issues to periods of time when the time is not focused on project activity and the participants are reacting negatively to one another. In this sense, the construct, Richness of Interaction, describes interaction relative to synergy. That is, richness refers to the amount of interaction behaviors observed and their association with synergistic behaviors.

(b) ***Richness of Media Use spectrum*** (Figure 1-5[b])*:* Conceptualizes media use as a process ranging from no use to medium use to rich use and varies as a function of utilization, access, interactivity, and purpose. The Richness of Media Use spectrum distinguishes between periods of time when the team uses no media and relies solely on human communication to periods of time when the team uses shared media, engages with the media by marking-up or changing information, communicates using the media, and uses the media to support project issues.

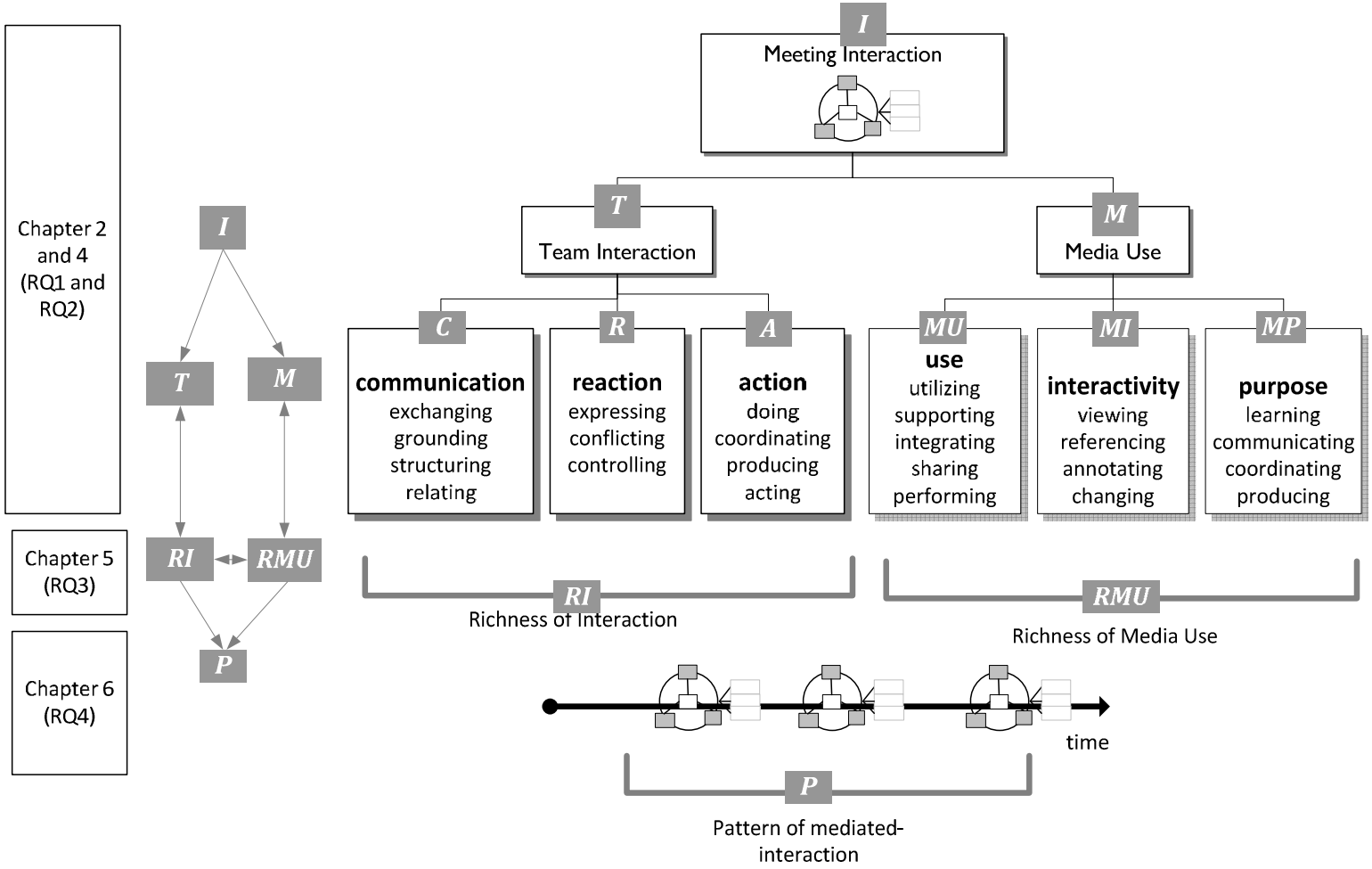
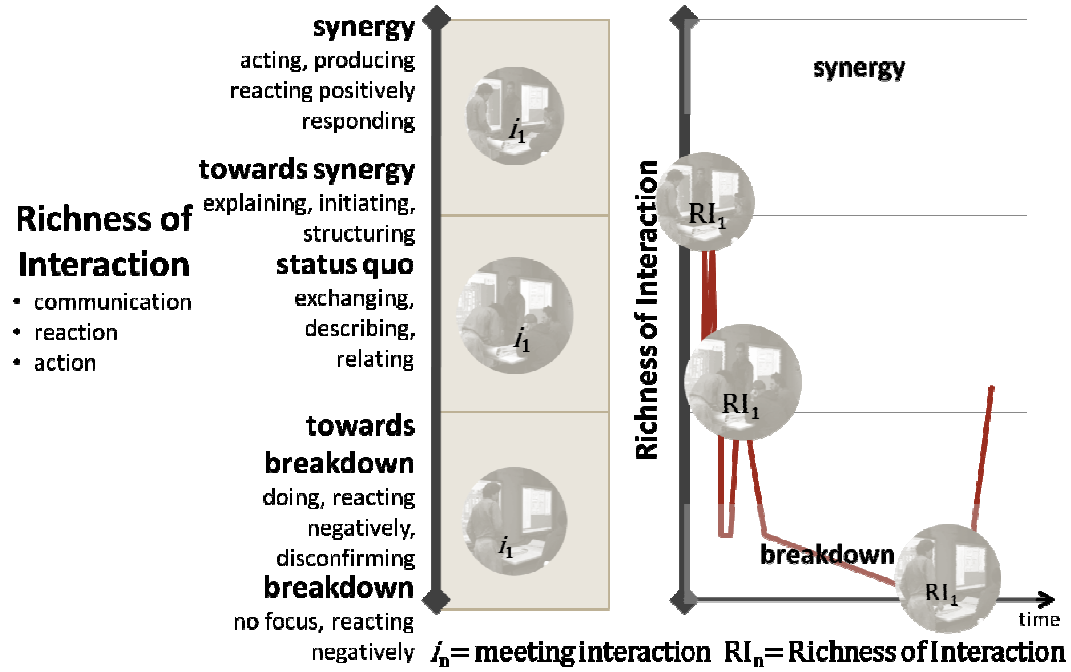
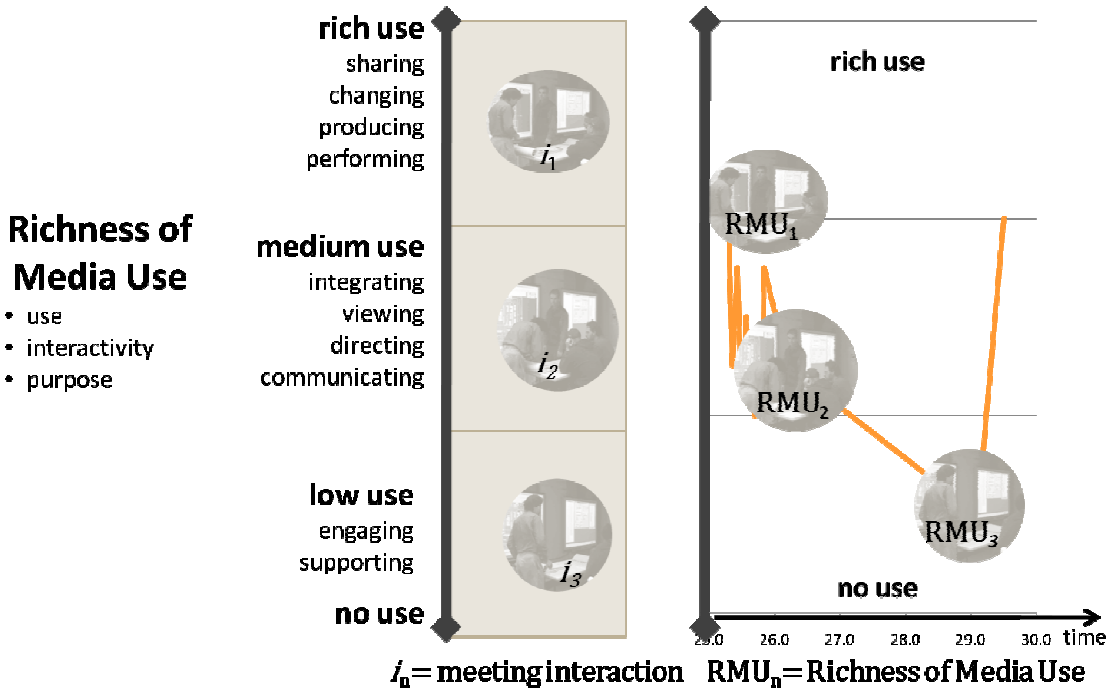


Figure 1-4: Elaboration of MIM in relation to the research questions and MIM concepts. The diagram shows the relationship of MIM processes for team interaction to behaviors associated with those processes. Chapters 2 and 4 discuss the rationale for this ontology and the analytic scheme that uses these concepts to interpret meeting interaction. Chapter 5 uses these processes to formulate two constructs to describe team interaction and media use respectively that use the analytic scheme and the MIM concepts. Chapter 6 relates these two constructs to describe patterns of mediated interaction and explore the relationship between media use and team interaction.



(a) Richness of Interaction Spectrum (RI)



(b) Richness of Media Use Spectrum (RMU)

Figure 1-5: Diagram showing the (a) Richness of Interaction and (b) Richness of Media Use spectra to describe differences in media use and interaction over time. Each spectrum shows three zones of interaction and media use. The middle zone represents typical observed behavior and the upper and lower zones represent less commonly observed interactions.

The final question addresses the challenge of describing and comparing patterns of mediated interaction:

(RQ4) How can the meeting process be visualized to describe and analyze the relationship between how teams interact and how teams use media?

I develop a Mediated Interaction diagram that orthogonally relates the Richness of Media Use spectrum (y-axis) to the Richness of Interaction spectrum (x-axis) as shown in Figure 1-6. This method visually and quantitatively compares *mediated interaction* for any set of meeting interactions. The "mediated interaction" line represents the moment-to-moment changes in team interaction and media use. The diagrams show the flow of interaction between zones of no media use and breakdowns to rich media use and synergy. The bubbles represent the time spent in mediated interaction zones. One can use the MIA visualization method to describe and compare patterns of mediated interaction relative to the range of behavior across the various mediated interaction zones (each box in the diagram represents a zone of mediated interaction), the profile of the overall "mediated interaction" line and density of the line within specific zones (Figure 1-6).

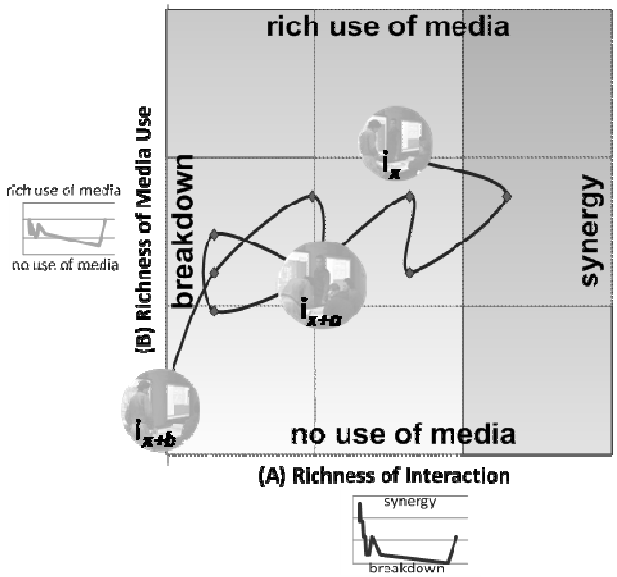


Figure 1-6: A MIA diagram that orthogonally relates the (A) Richness of Interaction Spectrum (x-axis) and (B) the Richness of Media Use Spectrum (y-axis) to describe the dynamic relationship between team interaction and media use. The "mediated interaction" profile shows a pattern of mediated interaction moving across zones of mediated interaction from no use of media to rich use of media and from breakdowns to synergies.

1.5 Research Process and Methods

The questions posed in this research require micro-level analysis of meeting interaction and development of multi-categorical constructs using observations of meetings. I used a mixed-method approach, combining qualitative and quantitative methods from Social Science and Organization Science. I did not adhere to a single philosophy or research approach, such as Case Study Methods (Eisenhardt 1989) or Grounded Theory (Glaser and Strauss 1967), or a specific epistemology such as positivism or interpretivism (Klein and Myers 1999; Searle 1999; Weber 2004). Since existing approaches did not

capture the richness of media use and team interaction, I chose methods and developed methods that allowed the data and observations to speak for themselves as much as possible.

The research process involved a set of iterative research tasks over four phases of research (Figure 1-7). The primary research tasks involved the observations of project team meetings and literature review to develop and formulate research concepts, development of constructs and operational definitions of those constructs, and validation of the methods (Figure 1-7). The following sections summarize the research tasks and methods employed in this research. I address issues related to the validity of the research, in terms of its generality, reliability, and construct validity. Chapter 3 discusses in detail the research methods employed in this dissertation.

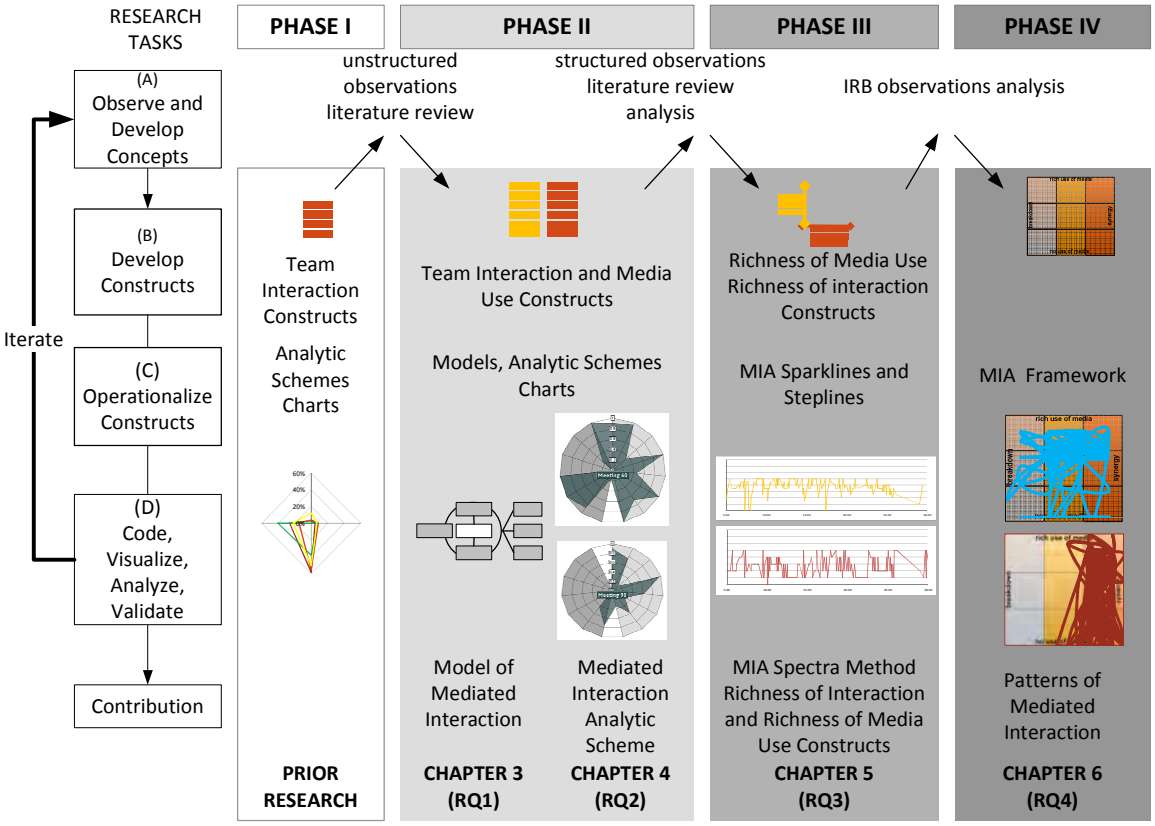


Figure 1-7: Diagram of the iterative research process, by phase, showing the relationship between the research tasks and the claimed contributions of this research. The tasks included: (A, B) developing concepts and constructs to describe meeting interaction from the two foci of analysis based on meeting observations and literature review, (C) operationalizing the constructs using coding schemes and methods developed in this research, and (D) applying those definitions to observations using interaction analysis and the MIA methods to analyze and validate the approach. The diagram shows examples of the results and describes the contributions in relation to those results from each phase of the research. The diagram also references the Chapters in this dissertation that elaborate these tasks and present the findings in response to the research questions.

1.5.1 Tasks and Methods: Observe → Generality

Over the four phases of research, I observed over 100 project meetings from twenty different projects, representing all phases of a project from conceptual design to construction using a wide variety of media. I

used a variety of ethnographic methods including informal interviews, notes, collection of documents and meeting handouts, photos, unrecorded observations, and recorded observations. In Phases III and IV, I followed Institutional Review Board (IRB) protocol to collect over forty hours of video-recorded meetings. In each phase, I observed face-to-face meetings with at least four participants representing multiple disciplines. Overall, I selected meetings to balance observations across different media—paper, digital, and mixed media—and different project phases.

1.5.2 Tasks and Methods: Coding → Reliability and Construct Validity

Formulating concepts and constructs to describe differences in media use and interaction involved iterative tasks of literature review and coding of the observational data. I employed three types of coding: open, axial, and selective coding (Corbin and Strauss 1990) using informal and rigorous interaction analysis techniques. Interaction Analysis (IA) involves the assignment of codes to portions or segments of video-recorded observations of teams. As I identified new concepts, using open coding, I used IA to operationalize the constructs and develop descriptive measures of media use and team behavior, e.g., a focus measure describing the time spent focused on project-related activity. I also used IA to perform axial coding and to compare categories of analysis and the process measures within and across observations. This addressed divergent validity to ensure that similar constructs were similar and dissimilar constructs were dissimilar (Zeller and Carmines 1980; Sethi and King 1991; Black 1999). To address reliability, multiple coders performed IA, and I calculated intercoder reliability measures for each coding scheme.

1.5.3 Tasks and Methods: Construct and Method Development→Construct Validity

I iteratively developed and operationalized the media use and team interaction concepts into the two richness constructs, the Richness of Media Use and Richness of Interaction. A challenge for any researcher is validating that the constructs measure what they are intended to measure. I used several methods to validate these constructs. First, I clearly define their operational definitions and assumptions in those definitions. Second, in developing those definitions and assumptions I rely heavily on prior literature, quantitative analysis of the meetings, and empirical analysis. Third, I present detailed breakdowns of the constructs using the Case Examples to illustrate these constructs and allow researchers to compare the narratives, transcripts, and photos to the results. With respect to validating the visualization methods, I provide visual evidence comparing those methods to prior methods. Table 1-1 summarizes the validation methods I employed in this research, the tasks I performed in relation to those validation methods and results related to validation of my research.

Table 1-1: Summary of the method, tasks, and results in the research.

Method: Theoretical Construct Validity	Task	Result
generality	observe and analyze multiple meetings of multiple types	• 100 + meetings overall • 40 + hours video-recorded • Application of methods to 9 meetings from four different project phases using paper, physical, and digital media
reliability	intercoder reliability	Krippendorf Alpha > .7 high inter-coder reliability
convergent / discriminant validity	compare multiple measures	• used schemes from prior research with results identifying relationships between process and outcomes • correlation analysis
	compare to satisfaction data	data for 4 meetings ranked similarly to richness of interaction construct
	compare within/across meetings	applied to 9 meetings showing differences within/across meetings

1.6 Findings Using MIA Approach

The following sections summarize the findings in relation to each claimed contribution: the MIA Mediated Interaction Model, MIA scheme, the MIA spectra, and MIA diagrams. I discuss key findings and the evidence for these contributions. These findings operationalize the Mediated Interaction Model and are evidence for the power of MIM to identify and explore the relationship between team interaction and media use. I limit the discussion to key findings using some quantitative data from applying the approach to nine project meetings. Chapters 4, 5, and 6 respectively elaborate these findings and discussion.

1.6.1 Findings Related to the Mediated Interaction Model and MIA Scheme

MIA analysis was a first step to break apart the meeting interaction into a set of behaviors, associated with MIM processes, and examine patterns of meeting interaction, albeit from a single focus of analysis. The MIA analytic scheme interprets the communication, reaction, action, and media use aspects of meeting interaction in relation to project, process, and interpersonal interaction. A comparative analysis of prior coding schemes shows that no single coding scheme captures these four aspects of meeting interaction at the three levels of analysis (see Chapter 4). The comparative analysis also shows that prior schemes miss two key aspects of meeting interaction. First, the schemes do not interpret non-verbal periods of media use from the perspective of team interaction. In several meetings teams spent significant time silently drawing, reviewing models, and these periods contribute to the teams' development of ideas and alternatives and understanding of the project. Second, the media use schemes do not capture transitions between different media and the combined use of media. Based on this comparative analysis, I selected three coding schemes from prior studies, made modifications to those coding schemes to address gaps or issues of interpretability and reliability, and developed three coding schemes. All coding schemes met acceptable standards for intercoder reliability. The comparative analysis, application of coding schemes to portions of data and

intercoder reliability data, are evidence for the MIA coding schemes' reliability, generality, and validity with respect to operationalizing the MIM concepts using observational data.

The results from applying MIA to nine meetings further demonstrate its power to capture differences in how teams interact and how teams use media. The results from proportional analyses show differences in meeting interaction in all MIM processes. For example, "utilizing" media ranged from 23% to 99% of the total meeting time ($\bar{x}$=71%, σ =.28) and "coordinating" meeting activity ranged from 4% to 16% ($\bar{x}$=10%, σ =.06). The keyword maps show patterns of behavior that emerge early in meetings and recur throughout the meeting, particularly behaviors associated with "coordinating" and "relating", but less distinct patterns for the media use processes. The findings also demonstrate the shortcomings of existing methods to describe patterns of mediated interaction. The keyword maps describe behavioral patterns from a single focus of analysis but are inadequate to identify relationships between two analytic perspectives, particularly for analyzing patterns over long periods, such as several minutes or two hours.

1.6.2 Findings Using the Interaction Spectrum Method and MIA Spectra

Patterns of team interaction and media use are established early in the meeting process and teams rarely deviate from those patterns. The MIA spectra describe the process of media use and team interaction and how these patterns emerge and recur throughout the meeting process. As evidence for the power and generality of ISM and the MIA spectra, I generated MIA spectra for nine meetings. The quantitative results from the RI spectra show that breakdowns and synergies are rare. Only five occurrences of breakdowns and one occurrence of synergy took place during the nine meetings in a total of thirteen hours and 4,689 meeting interactions. On average, teams spent 58% of the time in the "status quo" zone, 20% in the "breakdown" zone, and 22% in the "synergy" zone. The time spent in the "synergy" zone (see Chapter 5 for operational definition) ranged from 8-37%, and broken down further, ($2.5 < RI \leq 3$), the values ranged from 2% to 4%. The average value for the construct Richness of Interaction (RI) is 1.49, ranging from 1.25 to 1.79, where a value of 0 is complete breakdown and 3 is synergy and values 1-2 represent status quo.

The Richness of Media Use spectra show how teams move between periods of no use and rich use. It compares the extent to which teams use media in terms of frequency, access, level of interactivity, and instrumental purpose. Periods of no use ($0 \leq RMU \leq 1$) ranged from 2% to 88% ($\bar{x}$=34%, σ = .28) and rich use ($2 < RMU \leq 3$) from 0% to 73% ($\bar{x}$=29%, σ = .28). This wide variability conveys the wide difference in media use in the meetings I analyzed.

As evidence for the power of the MIA spectra to show the process of team interaction and media use, I generate RI and RMU Steplines and Sparklines for the nine meetings. These visualizations show the moment-to-moment changes and the degree to which some teams move towards synergy, others maintain status quo, and others struggle to maintain status quo; and visually show teams moving from no use to rich use. These spectra visualizations capture the "pulse" of team interaction and media use. Both capture "flatlines", regular rhythms, and irregular patterns. The RI spectra visualizations show that some teams never break out of the "low use" zone or "medium use" zone while others continually move from no use to

rich use of media. These findings from their application to nine meetings are evidence for the power and generality of the MIA spectra to describe and compare team interaction and media use.

1.6.3 Findings Using MIA diagrams

The MIA diagrams relate the two MIA spectra orthogonally to show the dynamic relationship between how teams use media and how teams interact. These diagrams distinguish patterns of mediated interaction based on: (a) the time spent in a zone of mediated interaction, (b) the frequency and regularity of movement across these zones, (c) density of the diagram in a zone, and (d) the overall shape, or "profile" of the diagram. The results from applying this method to nine meetings showed that teams develop patterns of mediated interaction early in meetings and rarely deviate from those patterns. Only in two meetings did the mediated interaction profile change dramatically after the first twenty minutes.

The MIA diagrams show the complicated patterns of mediated interaction. The two "ideal" patterns of mediated interaction were "cyclical synergy" (Figure 1-8[I]) and "balanced" (Figure 1-8[H]). Cyclical synergy is a pattern of moving between periods of rich media use and no media use while maintaining synergy through ongoing communication and positive reaction. These teams coordinated the media use through social interaction and media facilitation, integrating the media use into all team interaction processes. The "balanced" patterns of meeting interaction are when the level of media use is comparable to richness of use. This pattern occurs typically within the center, from the status quo-medium zone along the "mediated interaction" axis (Figure 1-8[C-A]). The two "non-ideal" patterns of mediated interaction were "transitional breakdowns" and "unmediated status quo". Transitional breakdowns are periods where the media use divides the team and contributes to the breakdown in communication. These situations involve transitions from shared to semi-shared or private media and separate the team into groups, ultimately leading to digression and sometimes frustration and negative expression between meeting participants. Unmediated status quo are periods of time when the team relies on conceptual knowledge to communicate issues and do not use any media. They spend prolonged periods trying to describe or explain something typically leading to disconfirmation or irresolution of a particular issue. Chapter 6 provides examples of these patterns and other mediated interaction patterns and associates these patterns with a list of recommendations for practitioners, media designers, and researchers based on these findings.

From this analysis, I postulate that teams mutually balance the processes of media use and team interaction. As teams move away from this "line of mediated interaction balance" they eventually move back to the line of mediated interaction balance (Figure 1-8[E to F] and [B to G]). The extent to which teams engage with media and integrate it with the interaction activity at all levels, *pushes* the team towards synergy. I did not observe teams that move towards synergy for any extended time without also moving towards richer use of media, paper or digital and vice versa. I did not observe teams that used media richly for extended time without moving towards synergy. This suggests a mutually dependent symbiotic relationship between media use and interaction in AEC meetings since the activity predominantly centers around the communication and exchange of visual information.

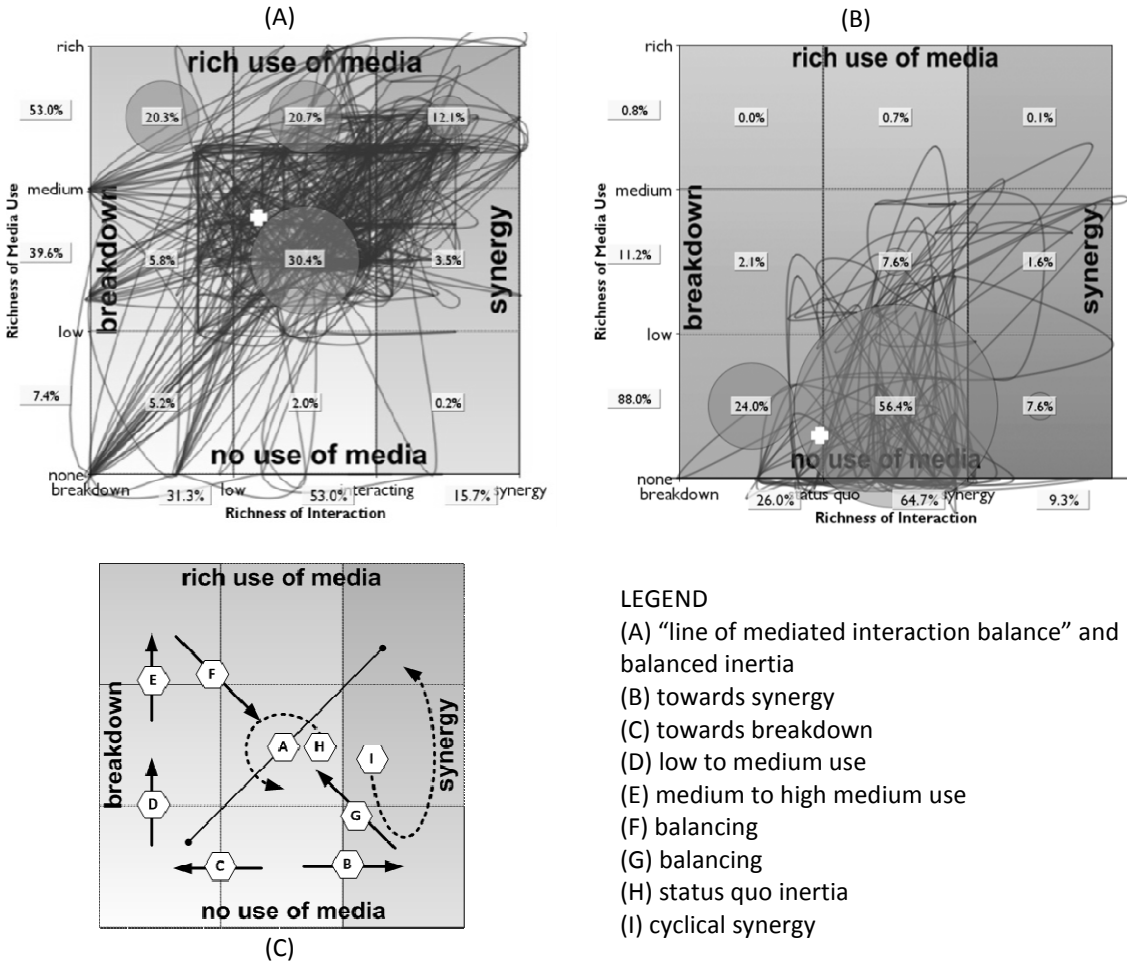


Figure 1-8: Examples of MIA diagrams for two project meetings showing and comparing patterns of mediated interaction for two two-hour meetings: (A) an unbalanced pattern of mediated interaction, (B) a pattern of low media use with status quo interaction. Overlaid on the MIA diagrams are bubbles indicating the percentage of time teams spent in each MIA zone. (C) A MIA diagram abstracting patterns of mediated interaction.

1.7 Implications for Practitioners, Media Designers, and Researchers

MIA is a departure from the idealized, task, and single media-oriented approaches to examine meeting interaction. It is no surprise that methods to improve meeting practice derive from the concepts of productivity and effectiveness and thus fail to address all aspects of team interaction. The perceptions of meetings as "bad" or "wasteful" follow since teams have no realistic perception of the purpose of meetings. It is also no surprise that methods to improve meeting media focus on media-specific features to improve specific tasks rather than examining the meeting context. MIA makes the fundamental assumption that how teams interact is as important as the artifacts they produce or tasks they accomplish. MIA approach offers a counter perspective on meeting interaction and what it should be and the role that media plays in that interaction. Instead of asking whether teams are productive, practitioners should ask if the team achieved synergy, and if so, how often? Instead of asking whether media led to increased productivity, media designers should ask if the media use played a role in synergy or played a role in mitigating breakdowns. Instead of asking whether media use triggers change, researchers should ask how media use leads to

synergy or whether synergy is possible without breakdowns and what role media use plays in that process. The following sections briefly elaborate this discussion from the perspective of practitioners, media designers, and practitioners. The discussion focuses on what I learned from developing and applying this approach and suggests a longer-term vision for meeting practice and meeting media.

Implications for Practitioners. Teams that view and enact a role of media as team player are more synergistic. Media plays a role in meeting interaction and the extent to which teams integrate media use into the core meeting processes—grounding, coordinating, and acting—shapes the effectiveness of the meeting interaction. The teams that balanced rich media use with periods of positive social interaction broke away from the status quo and established a rhythm of synergy. In the future, today's synergistic patterns will become the status quo as practitioners focus less on meeting outcomes or specific meeting media and more on balancing communication, reaction, and action and managing the use of media.

I make three key recommendations for practitioners. First, before investing in new media, do an informal assessment of current meeting interaction. This does not require the formal analyses presented here. Pay attention to the accessibility of media and the roles of meeting participants. In several meetings, teams could have avoided lengthy delays had someone in the meeting recognized the pattern of behavior as a "breakdown" indicator. Second, assign a role of "media facilitator" separate from a process facilitator whose primary function is to ensure that media is accessible and to structure and coordinate media activity either through knowledge of media features or managing those features. These changes should maintain status quo interaction and move the team towards synergy. Third, introduce new media or media features that support the full range of meeting processes, clearly assign functions to the media (supported by the media facilitator), and to the extent possible integrate the use of media into meeting management and use the media to structure and coordinate meeting activity.

Implications for Media Designers. Media designers enjoy the process of inventing new features and new media to solve perceived problems. The focus on digital media solutions ignores the benefits of traditional media or solutions that mix media. The MIA approach encourages media designers to think holistically about media design and its role in the interaction process and its relation to other media. The emphasis is not assessing media through specific performance criteria but in the extent to which practitioners use media in their meeting activity and in turn how media use relates to team interaction. Specific recommendations for media designers include consideration for transitions between media and development of a meeting media environment that supports grounding, coordinating, and acting activities. The selection and use of quality media contribute to the role that media play. However, the effectiveness of media, ultimately, is not a function of media-specific features but a function of the media environment, e.g., the layout, number of media, type of media, the media facilitation, and the extent to which the team engages with and integrates media use into its activity. Future media designers will assess media relative to both synergy and the extent to which teams engage and interact with media. Meeting media will evolve to play multiple roles, from communicator, coordinator, workspace, and producer and mix traditional and new media.

Implications for Researchers. How activity unfolds is just as important as the outcome of that activity. MIA conceptualizes interaction as the mutually interdependent process of media use and team interaction that makes meaningful, but relatively different, contributions to the systems within which teams interact. This conceptualization is a departure from prior models that emphasize the contingent factors that affect interaction or describe it relative to tangible outcomes. MIA offers researchers a means to describe moment-to-moment interaction using two richness constructs that relate interaction to status quo interaction and typical media use. It offers an alternative approach to relying on self-reported measures or idealistic constructs. The operational definitions of those constructs may not fit other researchers' specific analytic foci. These constructs and the spectrum method act as a template for future researchers to examine specific aspects of the meeting process, through either stripping away layers or adding additional layers to the analysis. Additionally, the operational definitions I employed will inevitably require re-calibration. Today's status quo may be tomorrow's breakdowns, and a new definition of synergy may emerge.

MIA visualizations tell the story of how media use and interaction unfold and how patterns emerge and recur at a micro-level, similar to other studies that identify such patterns at a macro-level. What triggers changes in these patterns or how do they unfold over a project? Examining a team in multiple settings may lead to a better understanding of the ways in which teams move from a limited role for media—as a backup or third string player—to a richer role for media—as a team player. Media potentially will reach a maximum level of influence or role in team interaction. Teams that enacted multiple roles balanced that with the roles of the team. In fulfilling their own needs to play a role, they may limit the role of media.

The detailed, micro-level analysis presented here was a means to delve into the rich process dynamics. I encourage researchers to review these methods but not necessarily follow those methods. Interaction analysis and the methods employed here are invaluable in identifying nuances in meeting interaction and allowed me to develop the skills to perceive and identify those nuances. At the same time, these methods are labor intensive and subject to challenges of interpretation (see Chapter 4). No abstraction of natural phenomena sufficiently captures or describes meeting interaction. I recognize that the MIA diagrams are "messy" and difficult to interpret in print. I foresee the need for researchers to share results interactively.

MIA is a step towards a normative model of meeting interaction and a science of media use and team interaction. MIA describes the complex relationship between media use and team interaction and provides future researchers with a template to examine aspects of that relationship at various levels of detail, to use the multi-dimensional constructs of Richness of Media Use and Interaction, and to build on and integrate other dimensions of media use and interaction. Chapter 2 develops the theoretical underpinnings of these constructs, i.e., the theoretical model of meeting interaction that builds on prior approaches to examine team interaction and media use.

Chapter 2: Background and Literature Review

"What we do is use the examples (literature) to stimulate our thinking about properties or dimensions that we can then use to examine the data in front of us."
(Strauss & Corbin 1998, p. 44)

2.1 Introduction

The study of team interaction and media use has a long history in multiple disciplines. These studies have led to a multitude of theories, models, concepts, and constructs to describe, predict, and compare team interaction and media use. Enfolding this wide body of literature into my research was challenging but also integral to developing my approach. I reviewed over 900 papers spanning five decades during ten years of personal observations. The literature enhanced my sensitivity to "nuances" in the meeting interaction (Strauss & Corbin 1998) and sharpened construct definitions (Eisenhardt 1989). My observations guided my analysis of prior approaches, and in turn, the literature guided the development of my approach. The literature review serves four purposes: 1) to develop the theoretical underpinnings of my research model and approach to study and analyze meeting interaction, 2) to identify and articulate the shortcomings of existing approaches, 3) to provide the theoretical basis for my research questions, and 4) to define my research model relative to prior research.

I reviewed the literature seeking answers to the following questions:

(a) What seminal models conceptualize team interaction and media use? What do studies using these models tell us about detailed natural meeting interaction? (Sections 2.2, 2.4)

(b) What common constructs do researchers use to describe and compare meeting interaction? Are these constructs applicable to study and analyze natural meeting interaction?(Sections 2.3,2.5)

I first answer questions (a) and (b) from the perspective of team interaction in Sections 2.2 and 2.3 and then from the perspective of media use in Sections 2.4 and 2.5. I use the criteria discussed in Chapter 1 and draw upon examples from the observations to assess whether various concepts and constructs are sufficient to describe and compare aspects of natural meeting interaction. Prior approaches to describe and compare team interaction have three primary shortcomings. First, the models and related concepts, constructs, and operational definitions are dependent upon static inputs, such as tasks and team-makeup, and tangible outcomes. This makes such models ill-suited for the study of meeting interaction. Second, no construct or set of constructs in the studies operationalize the communication, reaction, and action aspect of interaction. Third, the common constructs, such as productivity, performance, and effectiveness, are either idealistic and relate interaction to unattainable standards or their operational definitions are study-specific and thus insufficient to apply to a range of meetings. Prior models of media use are technology-oriented and do not support analysis of multiple media or establish a set of constructs applicable to multiple media contexts.

I conclude the chapter by proposing a model of the interaction process that builds on prior research (a) and (b) and addresses the shortcomings identified in (a) and (b), and answers (RQ1). *This Mediated*

Interaction Model conceptualizes interaction as two interdependent processes that are analyzable independent of process inputs and outputs. MIM builds on the concepts of multi-purpose, multi-level interaction and concepts of media use found in the literature, and conceptualizes that each meeting interaction is purposeful and analyzable in terms of its contributions to the project, meeting process, and/the interpersonal interaction. Chapter 4 extends this model, elaborates and operationalizes the concepts associated with each of the MIM processes and provides further evidence for the model conceptualization, with a comparative review of coding schemes introduced in this Chapter. Chapter 5 operationalizes the two high-level concepts of team interaction and media use and develops a method to visualize these processes. Chapter 6 develops a method to visualize mediated interaction and meeting interaction as conceptualized in MIM.

2.2 Approaches to Study Team Interaction

Team interaction is complex and dynamic (Ilgen et al. 2005; McGrath et al. 2000). Numerous disciplines, including Organization Science, Group Research, Social Psychology, and Design Studies, have studied what makes interaction effective and how teams interact leading to several influential paradigms and seminal theories of team interaction and team effectiveness. These include the Input-Process-Output (IPO) paradigm (Hackman & Morris 1975; McGrath 1964), Time Interaction and Performance Theory (TIP) (McGrath 1991), and Steiner's (Steiner 1972) model of group productivity. I discuss four fundamental contributions of these studies: 1) to describe and analyze meeting interaction as a sequential process of interdependent acts; 2) to examine team interaction as multi-purpose, 3) to examine the social and functional contributions of interaction to the project, process, and interpersonal interactions; and 4) to describe those contributions as process gains and losses.

2.2.1 Systematic Analysis of Interaction Process

The **I**nput-**P**rocess-**O**utput[2] (IPO) framework is the classic and influential paradigm for study of the group interaction process (Hackman & Morris 1975; McGrath 1964). The IPO model, conceptually shown in Figure 2-1, examines interaction in three discrete, contingent components of analysis: inputs, processes, and outputs. Hackman and Morris (1975) and McGrath (1964) identify three types of input factors: 1) *individual-level* factors, such as personality of individuals, gender, or expertise, 2) *group-level* factors, such as team tenure, structure, or size, and 3) *environment-level* factors, such as the type of tasks assigned to the group. Hackman and McGrath distinguish between two types of outputs to the meeting interaction process: 1) performance outcomes such as production or functional outcomes and 2) social outcomes that include group well-being and satisfaction. Many researchers invoke a "black box" perspective of the IPO model

[2] This discussion uses the terms outputs and outcomes interchangeably as did Hackman and Morris. The description of the IPO framework suggests that outcomes are a type of output. Outputs are tangible, e.g, a product, whereas outcomes are a level of performance or achievement associated with the process or an output to the process.

and investigate interaction by measuring inputs and outputs (Lebie et al. 1996). For example, studies on diversity in teamwork identify characteristics of the team that are associated with optimal outcomes. Findings from such studies are complex and contradictory, providing theoretical evidence to exclude such factors from analysis (Campion et al. 1996; Jackson 1996).

Hackman cautions against a "black box" approach as it fails to account for the role that process plays in affecting outcomes or account for changes to inputs that naturally occur over time. Hackman defines the interaction process:

> **interaction process (n):** "all observable interpersonal behavior that occurs between two arbitrary points in time (t_1 and t_2)" and that at any given point in time, the state of all variables, the inputs and outputs, may be assessed (Hackman and Morris 1975, p. 5).

A meeting is a type of interaction process, and as such, is analyzable relative to its inputs and outputs (Bostrom et al. 1993). Hackman further states that the interaction process "recycles" and outcomes affect inputs as denoted by the "feedback" loop in (Figure 2-1[A]). Many researchers fail to invoke this definition offered by Hackman or argue that the IPO framework does not account for the temporal nature of group work or changes to inputs, such as tasks, that naturally occur in interaction (Ilgen et al. 2005; Marks et al. 2001).

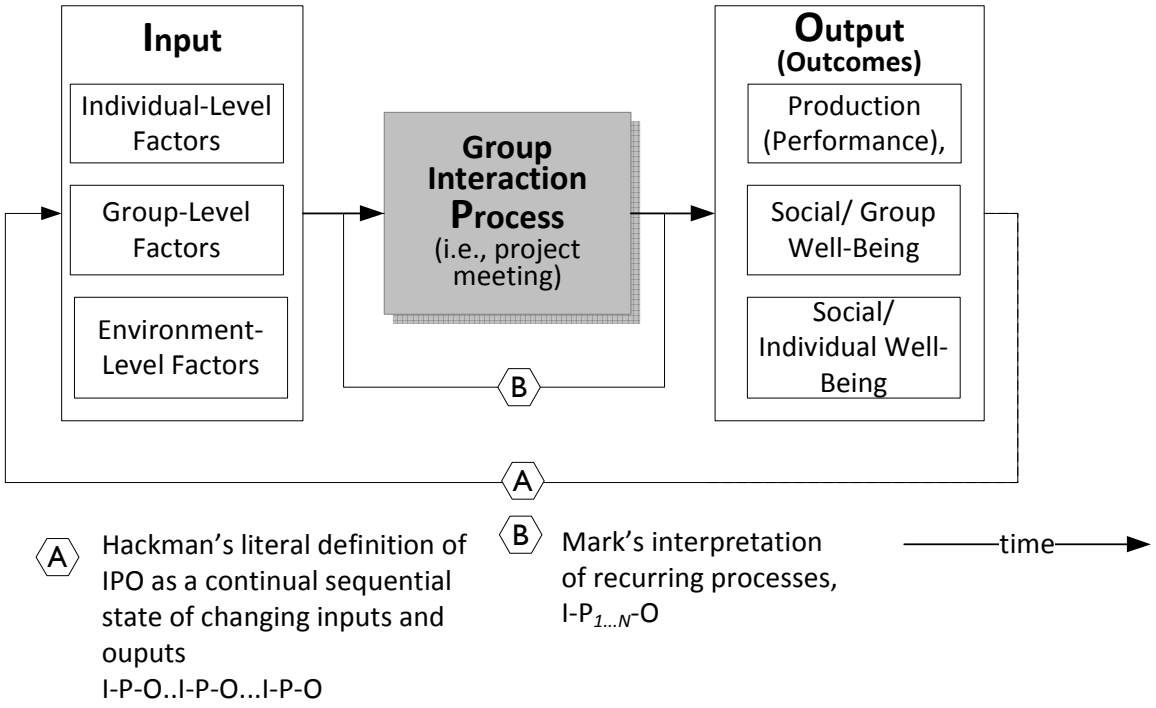


Figure 2-1: The classic Input-Process-Output (IPO) paradigm to analyze group interaction showing the interaction process as a mediator of outcome adapted from (Hackman and Morris 1975). (A) The feedback loop based on Hackman and Morris' (1975) definition of the interaction process that accounts for the temporal nature of interaction, and changes to input-factors throughout the process and to outcomes. (B) McGrath (1984) and Marks et al. (2001) extension of the IPO model to account for recurring processes that take place between assessable changes to inputs and outputs.

The "emergent" state model captures the temporal nature of interaction (Figure 2-2). According to Hackman and Morris, a formalized model of the interaction process is:

Formula 2-1: Conceptualization and formalization of interaction process based on Hackman and Morris' (1975) literal definition of the interaction process. The model conceptualizes the meeting process as a set of all interpersonal behavior, $\boldsymbol{B}$, from time t=0 to time t=N.[3]

$$interaction\ process = I = B = \{b_x, \dots, b_q\}$$

where $\boldsymbol{b_x}$ is any observable interpersonal behavior.

and:

Formula 2-2: Conceptualization and formalization of "emergent" state model of interaction based on Hackman and Morris' (1975) literal definition of the interaction process and subsequent interpretation by Marks (2001). The model conceptualizes the meeting process as a set of interaction states, $\boldsymbol{state_t}$, each of which is described as inputs and outputs.

$$\boldsymbol{interaction\ process = I = \{state_{t=0}, \dots, state_T\}}$$

where t=0 and T represent the start and end time of the observation of the meeting process and state is defined using the following properties:

Property	Description
time	time that state of interaction is assessed
inputs	individual-level
	group-level
	environment-level
outputs	production
	social

.

Marks et al. (2001, p. 358) note a problem with this model and subsequent interpretation of this approach to examine interaction. Marks argues that the intermingling of the concepts of emergent states and process in the literature has led to construct "contamination." Many of the so-called process constructs in the literature are output constructs and do not describe the process (Figure 2-2). This fundamental distinction is important as it differentiates studies that describe and measure the process versus those that describe and measure the inputs or outcomes of that process.

[3] See Appendix A.2 for a discussion and reference of the symbol notation and expressions used throughout this dissertation. Italicized variables represent a conceptual process and non-italicized variables represent a numerical variable. The {.,.} brackets refer to an unordered set of variables and $\langle .,. \rangle$ brackets represent a sequential set of variables.

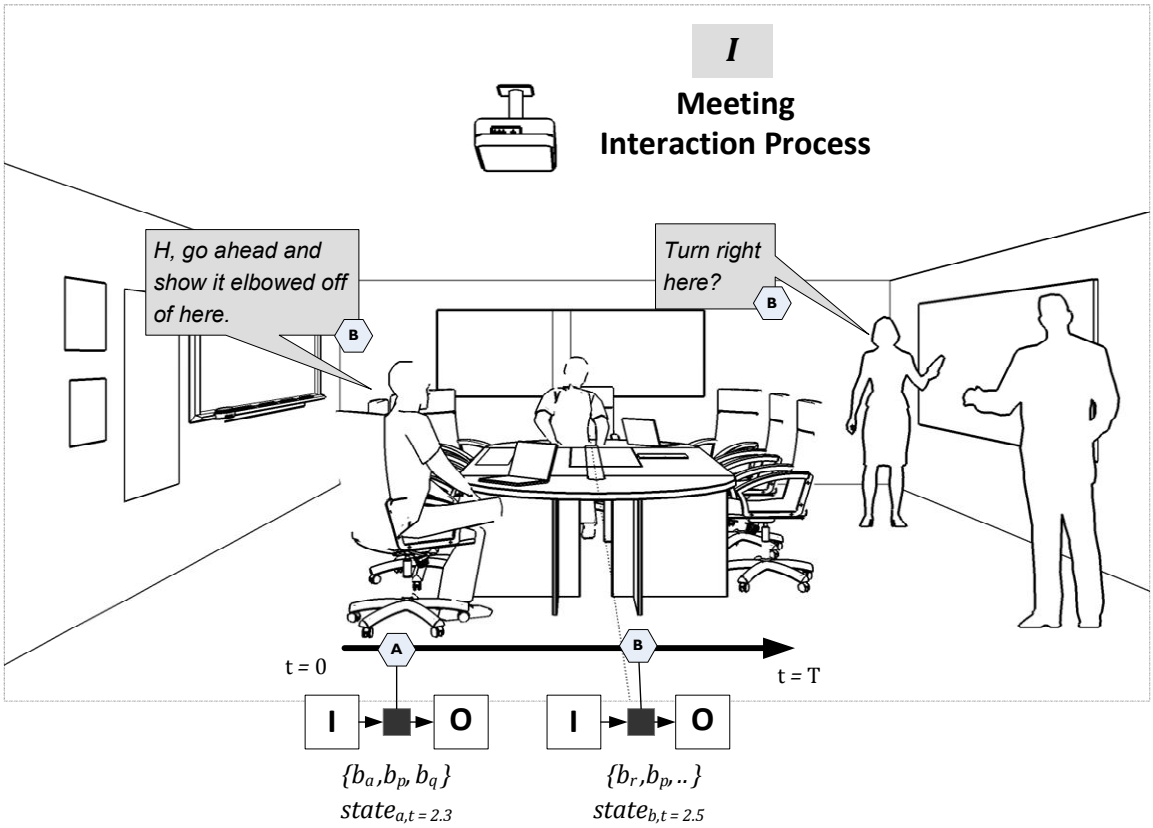


Figure 2-2: The "emergent" state perspective of interaction as defined by Hackman and Morris (1975) and Marks et al. (2001).

McGrath's Time, Interaction, and Performance (TIP) theory addresses the dependency shortcomings of IPO and provides further theoretical foundation to systematically describe and analyze the interaction process. TIP makes the following propositions:

(a) Interaction process is "flow of work in groups at a micro level". This emphasizes the process of interaction as opposed to states of interaction.

(b) A unit of interaction is "*a single act or input of a group member*" (McGrath 1991, p. 165). For example, the Case Examples in Chapter 1 segmented the interaction into discrete units of interaction.

(c) Each act can be referenced (has properties) as a) type of act, b) source and target of act, e.g., the speaker is the source and the target is the team, and c) time of act.

(d) At any point in interaction, a group has a purpose and objective and takes its meaning from the context in which it occurs. This elaborates the properties of an interaction.

(e) The flow of work, i.e., the process, is reflected in "different forms of aggregation of acts" (McGrath 1991, p. 168).

(f) Workflow analysis examines the sequences of acts, compares durations, and develops patterns or what McGrath calls "molar or more qualitative aggregation" of work in groups.

McGrath's *purpose-driven* model of interaction is a fundamental departure from the state-based IPO model that is input or outcome-dependent. TIP examines interaction as a set of discrete interactions, sequentially related to one another that are analyzable using a generic set of concepts and each researcher can select the specific concepts of analysis. Thus, according to McGrath, a model of interaction is a sequential set of interactions that are each independently analyzable (Formula 2-3). This model of interaction focuses on the process of interaction as opposed to the inputs and outputs of the process in Formula 2-1. TIP theory also establishes the basis to define patterns of interaction as a sequence or "aggregation" of interaction (Formula 2-4). This model of interaction, as conceptualized in Figure 2-3 moves closer to systematically describing how teams interact.

Formula 2-3: Formalized model of meeting process as a sequential set of interactions, $\boldsymbol{i_t}$ *, from time t=0 to time t=T based on McGrath's TIP theory (McGrath 1991).*

$$meeting\ process = interaction\ process\ = I = \{i_t, \dots, i_T\}$$

Where $\boldsymbol{i_t}$ is referenced using:

Property/Concept	Description
time	start of interaction
end	end of interaction
type	*
source	group member
target	group member(s)
purpose	*

*McGrath intentionally does not provide classifications or definitions for "type" and "purpose." The following section discusses the interpretation of these concepts.

Formula 2-4: Formalization of a pattern of interaction based on McGrath's TIP theory as an aggregation of sequential interactions.

$$pattern\ of\ interaction\ =\ P = \langle i_t, \dots, i_{t+x} \rangle$$

such that all members of P are members of I and P is a subset of I.

The methods suggested by McGrath's TIP theory are similar to observational methods developed by Mintzberg (1970), conversational analysis, discourse analysis, and interaction analysis, and ethnomethodology (Garfinkel 1967). These methods involve the categorization or coding of activity such as utterances, interactions, speech acts, or non-verbal behaviors to produce numerical data and measures of the interactions. Researchers use the resulting data to analyze the nature, sequence, and pattern of those interactions. The specific method employed in this study is Interaction Analysis (IA). Jordan and Henderson (1995) define IA as "*an interdisciplinary method for the empirical investigation of the interaction of human beings with each other and with objects in their environment*." A fundamental assumption of Interaction Analysis is that practice is situated in the interactions between members (Jordan & Henderson 1995) and can be used to understand how tools or artifacts are used in work practices. McGrath's TIP theory supports this perspective (Figure 2-3). Interaction Analysis (IA) involves video recording "naturally occurring talk and activity" (Frohlich 1993, p. 1), and systematically coding the observed events to classify and quantify the interactions (Bakeman & Gottman 1986). Chapter 3 discusses the methods employed in this research.

The primary challenge for researchers employing coding-based methods is the process of developing coding schemes that reflect and operationalize the research constructs and analytic foci. McGrath's theory, for example, identifies the high-level concepts of "type" and "purpose" leaving the researcher to further conceptualize and operationalize these concepts. Futoran et al. (1989) identify three types of coding schemes: activity-focused, process-focused, and discipline-focused schemes and they argue for a coding scheme that comprises these perspectives. The remainder of this Chapter discusses the theoretical research that influenced the development and selection of the concepts that guided the coding and systematic analysis of meeting interaction.

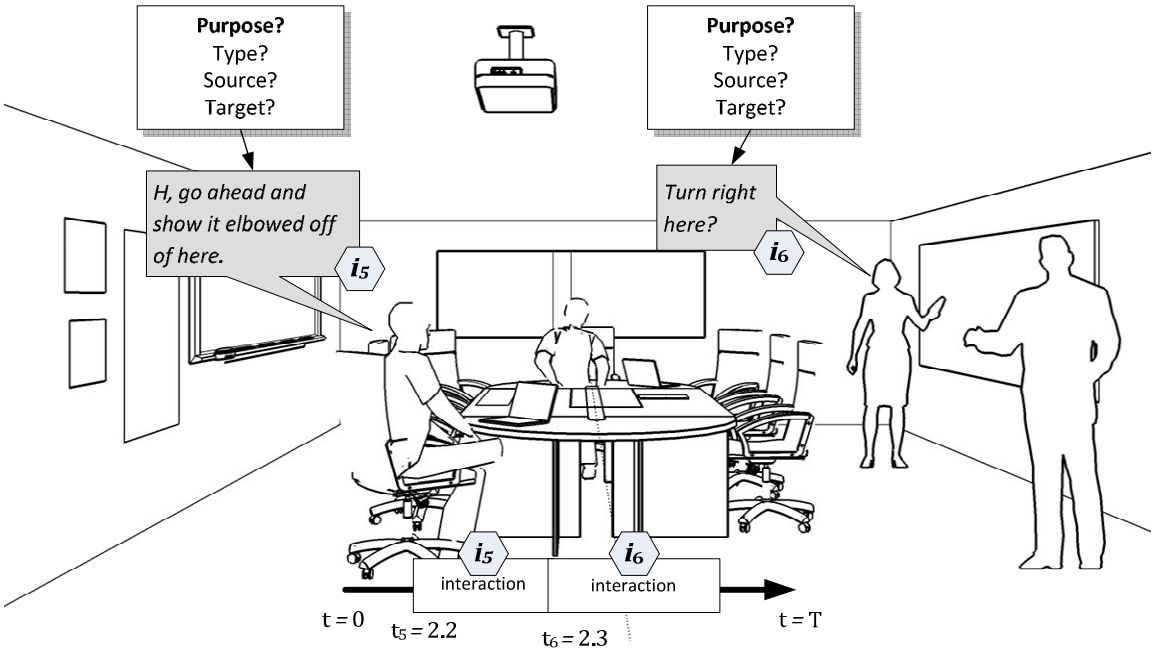


Figure 2-3: Conceptual view of meeting process based on TIP theory (McGrath 1964). The conceptualization decomposes interaction into a set of sequential interactions that in turn are analyzable with respect to the type, source, target, and purpose of the interaction. Using this model, researchers can describe differences in interaction relative to purpose and type of activity and identify workflow patterns.

2.2.2 Multi-Purpose Interaction

Both IPO and TIP conceptualize interaction as multi-purpose, engaging in social and functional-oriented interaction (Bales 1950; Hackman & Morris 1975; McGrath 1964). The social perspective views teams as social systems contributing to individual or team well-being and support of individual well-being. Social processes include conflict, dominance, socio-emotional response, cohesiveness, etc. Functional processes contribute to production or project goals. Common functional processes include decision-making, idea generation, grounding, resolving, coordination, etc. Bales' (1950) seminal work on groups in Social Psychology asserts that a group tries to maintain balance between the task (functional) and socio-emotional activities. Bales conceptualized and operationalized this *balancing* model of interacting using a coding scheme, the Interaction Process Analysis (IPA) (see Appendix K.3), to analyze interaction from a social

and functional perspective. Bales' seminal studies of groups in the lab identified patterns of social and functional interaction and relationships between social and functional behaviors and process outcomes. McGrath (1984) conceptualizes interaction as a "three stage" process having three mutual purposes: communication, action, acquaintance (social). I use the term *reaction* to represent this social-oriented perspective of interaction.

I build on this conceptualization of interaction since it further elaborates the functional purpose of interaction. This distinction is meaningful since much of the meeting interaction is not directly task or goal-oriented. There is also further theoretical evidence for this elaboration in Habermas' writings and rationale for distinguishing between communication and action (Habermas 1984). Habermas' Theory of Communicative Action identifies two functions of communication: 1) facilitate the sharing of meaning and information exchange which is the process of creating a "shared understanding" and 2) enlightenment, which has its focus upon the past and is distinguished from the organization of action that is future oriented. This distinguishes the two perspectives of communication and action.

Formula 2-5 formalizes the conceptualization of the meeting interaction process as three interdependent processes of communication, action, and reaction:

Formula 2-5: Formalization of interaction, I, as a set of three interdependent processes of communication, reaction, and action based on (McGrath 1984) and building on theoretical work by (Habermas 1984) and (Bales 1950).

$$I = \{C, R, A\}$$

$$C = communication\ process$$
$$R = reaction\ process$$
$$A = action\ process$$

2.2.3 Multi-Level Interaction

Groups engage in "purposeful activity" at multiple levels, i.e., projects, tasks, and steps (McGrath 1991) and make contributions to nested systems within which they interact, i.e., organization, project, and team. This conceptualization of groups as embedded in multiple systems is shared by Kast & Rosenzweig (1972) and Arrow et al. (2000). In this sense, it is apt to examine meeting interaction in relation to three system: the meeting process itself and the contributions made towards the tasks in the meeting, 2) the project in which the meeting makes contributions, and 3) the interpersonal interactions between a subset of the team, analogous to McGrath's "steps". Are these the appropriate levels of analysis and why are they relevant? I answer the latter part of the question here. I answer the first part in Chapter 4 and show how prior coding schemes focus on one or two levels of analysis but not all three, but there are sufficient examples for each level of analysis that it warrants examination. For example, we can analyze the interactions in the Case Examples in Chapter 1 in terms of their contributions to project-level goals, process-level goals, or interaction-level goals. Did a particular interaction solve a project problem? Did it address a meeting agenda item? Did the interaction address a question posed by another participant? If we analyze an interaction simply relative to contributions to project-level goals, we miss the contributions to the immediate needs of the team or miss the contributions to the meeting tasks.

Conceptualizing interaction as "making contributions" to multiple systems is a potential way to compare differences in moment-to-moment interaction, as each interaction makes relatively different contributions to each system. Futoran et al. (1989) operationalize this concept by developing a process coding scheme, Time-by-Event-by-Member Pattern Observation (TEMPO), that distinguishes two types of contributions: (a) process contributions made to how the group activity is undertaken (b) content contributions made directly to the group's outcome or product. Futoran et al. (1989) further differentiate these contributions as proposals or evaluations. Futoran et al. postulate that it is essential to study the "flow" of these contributions and pattern of those contributions if researchers want to understand the conditions that affect group performance. Although Futoran et al. propose this operational method, the study fails to present any examples of its application to natural interaction. I build on this notion that teams make contributions at multiple levels and conceptualize the total contributions of a meeting as the sum of the contributions from each interaction to the project, process, and interpersonal interaction:

Formula 2-6: Formalization of interaction as "making contributions" to systems based on McGrath's TIP theory. Teams make contributions, G, to multiple systems within which they interact (McGrath 1991). Process contributions, G, are equal to the sum of the contributions from each meeting interaction to the project, process, and interpersonal interactions.

$$process\ contributions = G\ = \sum_{\mathrm{n}=0}^{n=N} G_{\mathrm{n}}$$

where G_{n} represents the set of contributions for the nth meeting interaction to each of the systems within which the team interacts:

$$interaction\ contributions = \ G_{\mathrm{n}}\ = \ G_{project} + G_{process} + G_{interpersonal\ interactions}$$

Another way to conceptualize contributions is that at any time in a meeting, one can conceptualize the relative contributions of the interaction to these systems from each of the interaction processes. Futoran et al. (1989), for example, operationalize this concept distinguishing interactions based on the type of contributions they make to project goals or the process and the nature of those contributions as proposals that change project artifact, process, or evaluations. I build on this concept and extend it to apply to the multiple purposes identified thus far and to contributions made to the project, process, and interpersonal interaction. The interaction matrix in Table 2-1 formalizes this conceptualization. Sections 2.3 and 2.4 use this matrix to review and elaborate upon the specific contributions teams make to the multiple systems within which they interact. I also use this matrix in Chapter 4 to compare existing constructs and operational definitions to examine interaction from these nine perspectives.

Table 2-1: Interaction matrix to conceptualize the relationship between the interaction processes and the contributions they make to the project, process, and interpersonal interactions. Section 2.3 examines the specific constructs related to this framework.

	Interaction Processes		
Level of Analysis (contributions to…)	**Communication** G_c	**Reaction** G_r	**Action** G_a
project			
meeting process			
interpersonal interactions			

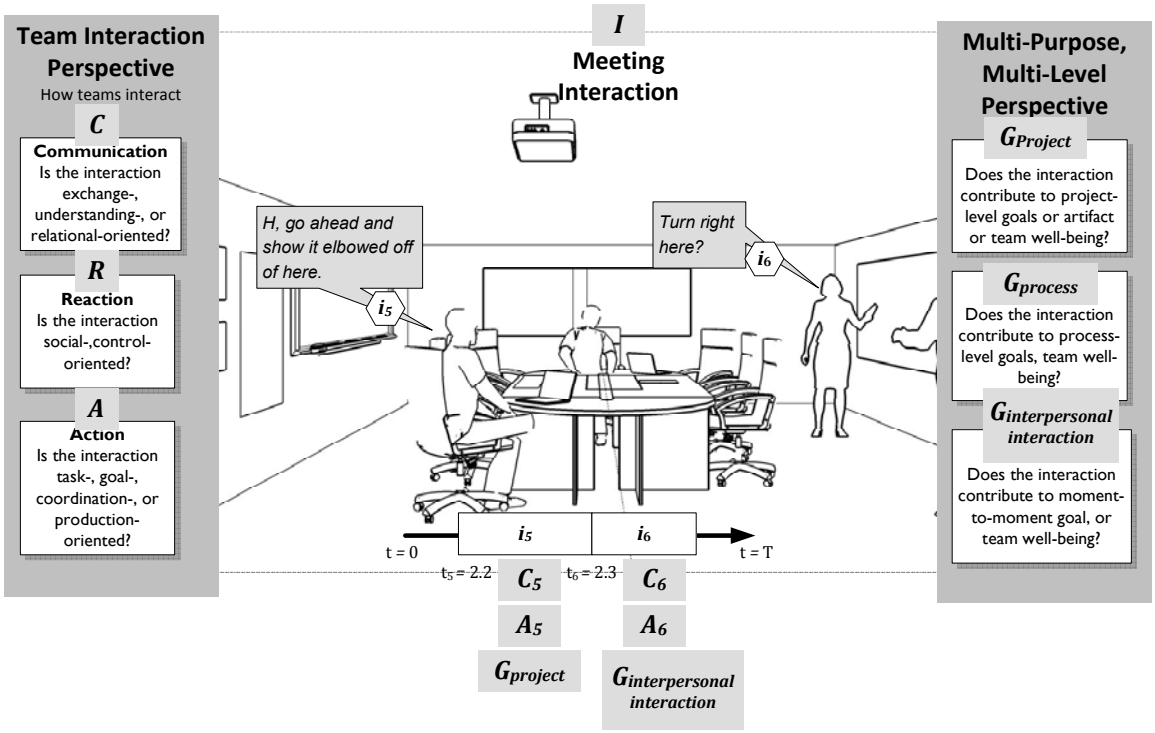


Figure 2-4: Conceptualization of multi-purpose, multi-level interaction combining McGrath's "three-stage" perspective of interaction (McGrath 1984) with TIP theory (McGrath 1991). Each interaction has one or more purposes and makes contributions to one or more systems. For example, i_5, has a communication purpose, C_5, and an action purpose, A_5, and makes contributions, $G_{project}$, to the project goal.

2.2.4 Process Gains and Losses

Another conceptualization of the interaction process that is similar to Futoran et al.'s (1989) "flow of contributions" is process gains and losses. Steiner (1972) introduces this concept in his seminal book "Group Process and Productivity" as a means to operationalize the construct of group productivity. Steiner posits that the productivity of a group is equal to its potential, ideal productivity minus faulty group processes (Formula 2-7). Steiner uses this model to compare group work to individual work and posits that

group work never reaches its potential due to the inevitable losses due to coordination between group members. The theoretical productivity is a function of member resources, such as skills, expertise, knowledge, and the task demands. Steiner proposes a typology of tasks that link task demands to resources: 1) additive (tasks that require equal effort by all team members), 2) conjunctive (tasks requiring input from two or more team members), and 3) disjunctive (requires input from one team member) (Steiner 1966). Mintzberg's (1980) and Thompson's (1967) also propose task taxonomies that compare tasks as a function of the level of coordination required to perform the task. Tasks in AEC project meetings are typically conjunctive but include additive and disjunctive tasks.

Formula 2-7: Formalization of the construct, group productivity, idealistically conceptualized relative to process losses based on (Steiner 1971).

$$group\ productivity = theoretical\ potential\ productivity - \ inevitable\ losses\ due\ to\ group\ process$$

where:

$$theoretical\ potential\ productivity\ = f(resources, task\ demands)$$

Steiner's operationalization of the construct is "idealistic" as it establishes a standard relative to a theoretical conceptualization of what group productivity should and could be. Steiner presents this definition but does not operationalize it using observational data. Steiner's work offers a conceptual link to describe changes over time and examine contributions as either gains or losses. This concept is analogous to contributions and is more widely accepted in the literature than McGrath's concept of contributions. Numerous studies use the gain/loss concept and operationalize these concepts to describe and compare processes in terms of gains and/or losses (Alavi 1994; Fjermestad & Hiltz 1998; Nunamaker et al. 1991a). Yet, the operational definition of those constructs relies on self-reported and post-process data.

The primary debate with respect to either of these concepts is whether to view the process as losses, gains, or as a combination of gains and losses. Researchers argue that the model does not account for process gains or argue whether gains or losses are theoretically possible. Nunamaker et al. (1991), for example, interpret Steiner's theory by allowing for process gains and losses. Nunamaker defines process gains as aspects of interactions that improve outcomes and process losses as those that impair outcome relative to efforts of an individual. Nunamaker et al. (1991b) suggest a modification to this equation that includes process gains and relates them to the multi-dimensional construct of group performance (a dimension of which might include productivity)[4]:

Formula 2-8: Formalization of the construct "group performance" based on (Nunamaker et al. 1991).

$$group\ performance\ = individual\ performance\ + process\ gains - process\ losses$$

[4] Steiner's description of productivity is also multi-dimensional since it includes social and functional aspects of interaction. However, operational definitions of productivity are typically a function of task-oriented output and resources.

Nunamaker et al.'s (1991b) view maintains Steiner's view of describing group productivity relative to individual performance. Hackman also combines elements of Steiner's model with the IPO framework and uses the concept of process losses and process "synergies" or interaction that reduces process losses to develop a normative model of group effectiveness (Hackman 1987). According to Hackman, a normative model of interaction is a function of the team's ability to maximize gains and minimize losses relative to task output, group-well being, and individual satisfaction. McGrath (1984, 1991) takes an opposing view to Steiner, stating group activity is always purposeful and one should not quickly label patterns as process losses. The concept of gains and losses is fundamental to my approach to study meeting interaction. It offers a way to conceptualize differences in team interaction relative to moment-to-moment gains and losses. That is, each meeting interaction makes contributions to the different systems within which the team interacts and these contributions vary relative to some standard. Theoretically, a meeting interaction that involves no communication makes different contributions to the project, process, or personal interactions than a meeting interaction that involves aspects of communication, reaction, and action. The challenge is operationalizing this conceptualization and quantifying or developing a standard to compare different contributions for different meeting interactions and the observed behaviors. Chapter 5 continues this discussion and operationalizes this conceptualization.

2.2.5 A Conceptual Framework to Systematically Describe and Compare Meeting Interaction

In summary, the prior studies contributed to my conceptualization of a model (Figure 2-5) of interaction that makes the following assumptions:

(a) A project meeting is an interaction process (I) from time t=0 to t=N and is analyzable as a set of discrete interactions (i_n) (McGrath 1991).

(b) Interactions are observable through the behaviors of the individuals acting as a functional unit (Hackman and Morris 1975; Cannon-Bowers & Converse 1993).

(c) Meeting interaction is the interdependent processes of team interaction (T) and media use (M) (DeSanctis & Poole 1994; Orlikowski 1992; Orlikowski 2000).

(d) Team interaction process is made up of three interdependent processes of communication (C), reaction (R), and action (A) (McGrath 1984; Habermas 1984).

(e) Team interaction make contributions (G) to the project, process, and interpersonal interactions (McGrath 1991).

(f) These contributions (G) are describable as process gains (G) or losses (L) (Hackman 1987; McGrath 1991; Steiner 1972; Nunamaker 1991b).

(g) A pattern of interaction (P) is a set of sequential interactions and is assessable in terms of its contributions to the project, process, and interactions (Futoran et al. 1989, McGrath 1984).

The following section uses this conceptual model as a basis to review specific concepts and constructs to elaborate aspects of this model and develop methods to operationalize its concepts.

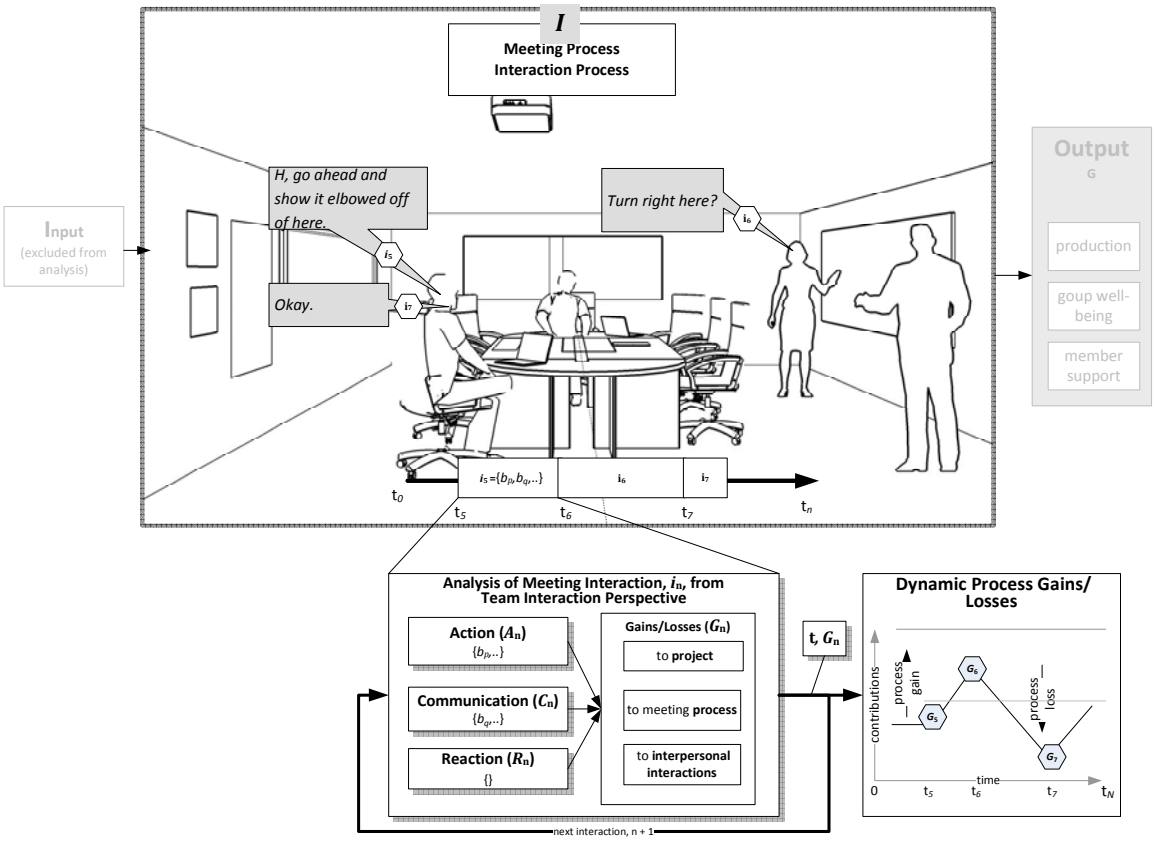


Figure 2-5: Conceptualization of a model of interaction integrating concepts and methods to: a) analyze interaction process as a discrete set of interactions (McGrath 1964;Hackman and Morris 1975), b) to analyze each discrete interaction relative to multiple purposes and contributions to multiple systems (McGrath 1984, 1991), and c) to describe those contributions dynamically as incremental gains and losses (Steiner 1972, McGrath 1991).

2.3 Team Interaction Concepts and Constructs

This section reviews concepts, constructs, and operational definitions that use observational coding methods associated with communication, reaction, and action processes. I identify theoretical evidence for those concepts and any evidence for associating differences in those constructs with process gains or losses. I use the interaction matrix framework to synthesize this review and further elaborate the conceptualization of each of these processes. I show that while many studies use different labels or operational definitions, there are common aspects of interaction that researchers examine with respect to the particular perspective of interaction. The review shows that few studies use observational data to operationalize these concepts, and only a small set of studies examine differences in any aspect of team interaction in moment-to-moment interaction. Chapter 4 extends this discussion with a comparative analysis of coding schemes prior researchers developed to operationalize the communication, reaction, and action aspect of team interaction. Here, I introduce those studies and coding schemes and the concepts that I further examine, and, in some cases, elaborate those concepts further in Chapter 4.

2.3.1 Interaction as Communication

The communication perspective views interaction as understanding, relational, and information-oriented (Galbraith 1977; Habermas 1984; Hinsz et al. 1997; Kunz et al. 1998; March & Simon 1958) and teams make contributions to the ongoing relational interaction, the process structure, and shared understanding of the project. A wide range of studies examine this perspective of interaction including relational communication studies that examine the relational and processual aspects of communication (Rogers & Farace 1975), linguistics and communication studies that examine the content and processual aspect, and a broad range of organizational and design studies that look at communication in organizational context. From these studies, I identified five concepts that researchers commonly examine in relation to the communication-oriented perspective: exchanging, grounding, structuring, initiating, and responding.

Exchanging. Communication involves the exchange of information, and studies show that the team's ability to process information affects the outcomes of the team interaction (Gladstein 1984; Salas et al. 1992). The demands on teams to process information are a function of task dependencies, task complexity, and task uncertainty (Buckland & Florian 1991; Byström & Jarvelin 1995; Galbraith 1974; Thompson 1967). Meeting tasks vary from planned to unplanned, synchronous to asynchronous, and questions seeking a simple dimension from one participant to others requiring input from multiple participants. It is challenging to use observational data to describe the varying information processing demands since it requires several levels of analysis. First, it requires analysis of whether a particular interaction involves the exchange of information, and whether it is project related or not. Olson et al. (1992), for example, distinguish between project-related activity and non-project related activity. Second, it requires analyzing the type of information that is the content of the message. For example, I use a typology of information germane to AEC, called Product, Organization, and Process (POP, see Appendix J.8) (Fischer & Kunz 2004). Third, it requires analyzing the relation to the type of task or question or to determine its complexity or dependencies.

Several studies illustrate examples of these three levels of analysis in natural interaction. Garcia et al. (2003) analyze the task dependencies of tasks using the DEEPAND coding scheme. DEEPAND distinguishes between informational tasks that should be done in meetings, requiring input from multiple team members, to those that do not (Garcia et al. 2003b). Garcia uses this coding scheme to operationalize constructs for meeting effectiveness and meeting value and uses these constructs to demonstrate agenda-planning methods to improve meetings. Baya (1996) examines "information fragments" (similar to an interaction) in terms of the semantic information and quantity of semantic information using an Information Handling Framework (IHF, see Appendix J.5). Baya also looks at the transitions designers make between "handling" different information in relation to tasks. Baya operationalizes a design information measure (*dim*) to compare information handling rates of groups. For example, Baya finds that designers spend between 2 to 35 seconds handling one piece of information. Baya uses this measure and IHF coded data to gain insights into design activity but did not formalize a model or identify relationships between the design behaviors and media use. Maznevski & Chudoba (2000) look at "intensity" and frequency of

communication and information exchange over time and identify patterns of information exchange. Maznevski and Chudoba's study is one of the few studies that examines changes in a construct over time, but did not relate those changes to other aspects of interaction or media use. These studies demonstrate several methods to describe differences in information exchange in groups. These studies do not relate "exchanging" to other aspects of interaction or to media use.

Grounding (Describing and Explaining). Teams spend a predominant amount of time in meetings *grounding* or developing shared meaning or a shared model (Clark & Brennan 1991; Olson et al. 1992). The concept of a shared model is found in many disciplines using multiple terms: mental model, object world, shared mental model, team mental model, frames, and conceptual information space (Bannon & Bødker 1997; Baya 1996, Bannon 1997; Bucciarelli 1988; Mackinlay et al. 1991; Orlikowski & Gash 1994). Bucciarelli (1988) describes this concept as "object-worlds" or the intangible world of information related to the "artifact-to-be" and the design process and which resides in no single artifact or artifacts but in the space of interaction. Shared models enable teams to understand, make decision, and "understand the world by constructing mental models of it in their mind" (Johnson and Laird 1983, p. 10 as cited in Cannon-Bowers and Converse 1993). The team mental model is the notion of a shared representation of tasks, work relationships, and artifact-to-be. Creating a shared understanding and the process of creating that shared understanding is a critical aspect of team interaction. Several researchers identify a link between shared mental model and team performance (Stout et al. 1999; Mathieu et al. 2000).

Multiple coding schemes capture the process of grounding. For example, the Collaborative Design Workflow (CDW) coding scheme includes a category, "taking stock" and the DEEP(AND) coding scheme includes coding categories for "describe" and "explain" (Garcia et al. 2003a; Liston et al. 2001). Multiple studies also distinguish between the level of grounding or phases of grounding (Olson et al. 1992). Eris (2002) and Graesser et al. (1988), for example, classify "deep reasoning" questions as those that demonstrate deeper understanding. Eris (2002) identifies a relationship between teams that ask such questions, deep reasoning questions (DRQ), to those that ask other types of questions. Minneman's (1992) Activity Design Framework (ADF) (see Appendix J.6) also distinguishes between communications that describe the *state of* the project to those that *make sense of* the project. Minniman uses ADF to show the process of designing but does not relate the process to other aspects of interaction or to media use. These studies and the coding schemes establish a theoretical basis to describe the grounding process at three levels of analysis: (a) with respect to describing the state of the project, (b) distinguishing between levels of understanding, and (c) the relation to project, process, or personal interaction level issues.

Structuring. Structuring is the process of communicating rules, goals, and strategies for the process. Bales (1998) refers to this as "giving guidance" and Olson et al. (1992) distinguish between an interaction communicating a "goal" to managing or coordinating. This distinction is important as few teams make their goals or strategies to achieve those goals explicit particularly in the meeting context. A facilitator or agenda often act as the mechanism whereby teams make these goals explicit. Of the 100 meetings I observed, though, few had formal agendas and only one used a facilitator.

Relating (Initiating and Responding). The process aspect of communication examines the flow and pattern of communication between sources of communication. Bales (1951, 1976, 1998) examines the question and asking pattern of communication. Rogers and Farace (1975) examine two aspects of communication: the format and response mode of the communication. This coding scheme, Relational Coding Analysis (RCA), distinguishes between utterances that initiate and terminate to begin and end an "interaction", e.g., a request, issue, or topic. This perspective of the communication is a critical and meaningful one. It establishes the structure of the conversation and a means to interpret that structure. A concept that closely relates to this process aspect is *closed-loop communication*. Closed loop communication involves: "(1) sender receives message; (2) receiver accepts message and provides feedback that it was received; and (3) sender double checks to ensure message was received as intended" (Salas et al. 2000, p. 348). Studies show that closed-loop communication is a characteristic of more effective team interaction (Bowers et al. 1998; McIntyre & Salas 1995). The language/action perspective shares a similar conceptualization of communication focusing on the request and response process of communication (Winograd 1988).

The processes of initiating and responding also closely relate to aspects of action. A question that requests clarification of an issue is different from a question that proposes an alternative. Similarly, a statement that initiates a new topic or identifies a problem is different from a statement that initiates discussion on a previously identified issue. Likewise, a response that clarifies an issue is different from a response that makes a decision. These distinctions represent the two simultaneous perspectives of interaction as communication and action. I address this distinction through multiple coding schemes that allow for multiple interpretations.

In summary, a formalized model of the communication process is:

Formula 2-9: Formalization of a model of the communication process based on prior studies.

$$communication\ \ process = C = \{exchanging, grounding, structuring, relating\}$$

This model reflects the common perspectives of communication at three levels of analysis and summarized in Table 2-2.

Table 2-2: Summary of review of concepts and constructs related to conceptualization of interaction as communication. Chapter 4 further analyzes these concepts using the bold coding schemes.

	Communication Perspective of Interaction					
Level of Analysis	Conceptualization	Process	Questions	Constructs	Why examine the process?	Coding Schemes
Project	understanding-oriented	grounding	Is team seeking rationale?		Do differences in time spent grounding relate to differences in media use?	**DEEP,CDW**
		describing	Is communication future-oriented? Past-oriented? Is team seeking shared understanding?	# of comments, # of questions/ answers	Do differences in time spent on future-oriented or past-oriented communication elate to differences in media use?	DRQ, **DEEP,** Goldschmidt
	exchange-oriented	exchanging	Is team exchanging project information? Is the content of the message project-related?	information handling	Do differences in time spent communicating project information (focusing) relate to differences in media use?	IHF, **DEEP, POP**
Process		structuring	Is team communicating process goals?	dominance, structure	Do differences in time spent structuring the communication relate to differences in media use?	DRQ
Interpersonal Interaction	relational-oriented	Responding /initiating	Is team responding?	questions/ answers, closed-loop communication	Do differences in time spent in closed-loop communication relate to differences in media use?	**RCA,** LA

CDW=Collaborative Worfklow Design (Olson et al. 1992), see CWA in Appendix K.1
DEEP = See Appendix K.6
DRQ = Deep Reasoning Questions (Eris 2002)
IHF = Information Handling Framework (Baya 1996), See Appendix J.7)
IPA = Interaction Process Analysis (Bales 1950), see Appendix K.3
POP = Product, Organization, Process (Fischer and Kunz 2007)
LA = Language/Action (See Chapter 4, Figure 4-1) (Winograd 1988)
RCA = Relational Communication Analysis, see RWA in Appendix J.4

2.3.2 Interaction as Reaction

The social perspective views interaction as expressing, control, and dominance-oriented and ensure team well-being by maintaining commitments to team, fulfilling member needs, and to support its members (McGrath 1964; McGrath et al. 2000). These conceptualizations of interaction are associated with constructs such as team-building, conflict, commitment to team dominance, socio-emotional expression, social loafing, and apprehension (Evans & Dion 1991) (Fleishman & Zaccaro 1992; Gibson et al. 2000; Jackson & Harkins 1985; Latane et al. 1979; Williams & Karau 1991). Several studies cite positive correlations between these constructs and process outcomes (Bales 1951, 1998; Evans & Dion 1991; Gibson 1999; Kuhn & Poole 2000; Pescosolido 2003; Campion 1996; Yu 2005). Typically, researchers do not operationalize these constructs using observational data. For example, studies examining cohesiveness use self-interpretive data to measure *perceived* social cohesiveness. This is primarily due to the challenges of relying solely on observable behavior to assess these social processes. For example, how does one interpret the team spirit or cohesiveness in moment-to-moment interaction?

I identified three concepts that researchers commonly examine in relation to the reaction-oriented perspective and that prior researchers operationalize using observational data: expressing, controlling, and dominating.

Expressing. Frustration, anger, joy, laughter are examples of "expressing." Classifying and distinguishing these behaviors in moment-to-moment interaction is challenging and hazardous (Rafaeli & Sutton 1987). Bale's (1950) seminal research offers a simple and powerful approach to classifying interaction as either positive or negative expressions (Bales 1950, 1976). It asks a simple analytic question: "Is the member expressing positive or negative emotion?" Bales' Interaction Process Analysis (IPA) coding scheme uses three codes for positive and negative emotions respectively (see Appendix K.3). Bales applies this scheme to thousands of groups and generates "interaction profiles" for those groups (see Figure 3-9 for example of interaction profiles). These profiles compare counts and frequencies of positive and negative socio-emotional expressions and questions and answers. Bales identifies correlations between groups with high counts of positive expressions and giving direction with outcome measures of satisfaction. This suggests the effects of positive expression on individual well-being. Bales' studies, though, did not examine how the moment-to-moment relationship between socio-emotional processes and action or communication processes relate to one another. Gorse and Emmitt (2007) use IPA to analyze communication behavior of AEC professionals in construction project meetings. Gorse and Emmitt find that AEC teams have nominal levels of socio-emotional interactions and negative emotion. They, too, do not examine the relationships between the socio-emotional process and other interaction processes.

Conflicting. Conflict refers to deeper levels of expression between team members. Conflict occurs in relation to competing ideas, personal disagreements, and organizational roles. Conflict is a natural stage of group work (Bales 1950; Tuckman 1965; Poole and Roth 1989a). Several studies examine the occurrence of conflict in natural interaction. Bales' scheme distinguishes between simple disagreements and behaviors showing tension or antagonism. Poole and Roth (1989a) examine conflict in working groups using the Group Working Relationship Coding Scheme (GWRCS). They examine conflict in relation to use of a group decision-support system (GDSS) and identify differences in conflict as a function of structure imposed with the GDSS system (Poole et al. 1991). Walz (1988) examines the process of conflict in relation to design process and finds that conflict increases and decreases as a function of the tasks the team performs. These studies demonstrate examples of examining conflict in group interaction and cite relationships to outcome. However, these studies do not examine the process of conflict in relation to all aspects of interaction and to media use.

Controlling. Dominating refers to a single team member speaking for a relatively greater portion of time than other meeting participants do (Connolly et al. 1990; Diehl & Strobe 1987). Researchers most commonly operationalize the concept of dominance as proportion of speaking time, turns, or counts (Adrianson & Hjelmquist 1991; Foley & Macmillan 2005). A standard measure for participation is the Gini Coefficient (Folger & Poole 1982). The Gini coefficient measures equity (1.0) or complete dominance (0.0) (See Appendix H for description of Gini coefficient). A simple participation coding scheme (PCS) (see

Chapter 3) that labels each interaction in relation to a team member captures the information necessary to calculate the Gini coefficient or other dominance measures. The challenge with these measures is that it is difficult to interpret the results. Is equal participation an idealistic measure or a realistic one? Researchers typically use self-perceived measures of equity to operationalize the dominance construct as opposed to these quantitative measures (Flanagin et al. 2004). Another issue with this measure is that it captures the equity of participation for a set of interactions and is not readily applicable to interpret equity or dominance for a discrete interaction.

Another aspect of dominance is the intent of the verbal utterance that orders or instructs other team members to do something without solicitation for feedback. Bateson (1958) refers to this aspect of communication as *control* as do Folger & Poole (1982), Rogers & Farace (1975), Watson (1982) and Bednar (1983). I include this under the reaction aspect of interaction since it is closer in concept to dominance than the communication-oriented views discussed previously. Sluzki and Beavin (1977) and Rogers and Farace (1975) operationalize Bateson's concepts with a sophisticated coding scheme and a process to analyze the transitions between interactions using the coded data. These schemes analyze the relational control in dyadic groups but demonstrate how to capture the control aspect of communication. Their studies, though, do not associate patterns of control with other process constructs or outcomes.

Table 2-3 shows the relationship between the conceptualizations of interaction as reaction-oriented and the reaction processes, analytic questions, and process constructs. Note that the team well-being conceptualization is not associated with any coding schemes because these behaviors are not readily observable. This is one shortcoming of relying solely on observational data. These behaviors are to some extent observable through the processes of expressing, dominating, and conflicting. The seminal work by Tuckman (1965) and Tuckman and Jensen (1977) posits that groups go through four stages, "forming", "storming", "norming", and "performing". Tuckman associates the process of "norming" with the development of group cohesion. These processes typically play out across multiple meetings. Aspects of these processes are observable in meetings and potentially can yield some data to interpret team well-being through the conflicting and expressing behaviors. I posit that through examination of the conflict and expressing processes it is possible to capture the contributions interactions make to team well-being. In summary, a formalized model of the reaction process based on prior research and analyzable using observation data comprises four processes: participating, expressing, controlling, and conflicting:

Formula 2-10: Formalization of a model of the reaction process based on (Bales 1950) and (Bateson 1958).

$$reaction\ process\ =\ R = \{participating, expressing, controlling, conflicting\}$$

Table 2-3: Summary of concepts and constructs associated with social processes. The table lists the various conceptualizations of social processes in relation to the level of interaction, the types of questions associated with examining the process, the common constructs, the reported gains and losses associated with the construct, and coding schemes developed to operationalize the concept. Bold constructs refer to the constructs examined in this dissertation, and Chapter 4 further analyzes the bold coding schemes.

Social Perspective of Interaction						
Level of Analysis	Conceptualization	Process	Questions	Constructs	Why examine the process?	Coding Schemes
Project	team well-being oriented	team-building	Is team working together? Does team believe in its own capabilities?	cohesiveness (Evans & Dion 1991), commitment to team, group efficacy (Fleishman & Zaccaro 1992; Gibson et al. 2000)	Do differences in cohesiveness relate to differences in media use?	None.
Process	member-support-oriented	**conflicting**	Are members taking opposing sides, and is opposition personalized? Managed?	conflict	Do differences in conflict relate to differences in media use?	**GWRCS**
		controlling/ dominating	Is member controlling the process	dominance	Do differences in dominance relate to differences in media use?	**IPA, RCA, PCS**
Interpersonal Interaction	individual well-being oriented	**expressing**	Is member expressing positive or negative emotion?	positive, negative	Do differences in emotion relate to differences in media use?	**IPA, PAC**

GWRCS = Group Working Relationship Coding System (Poole & Roth 1989a), see Appendix J.3
IPA = Interaction Process Analysis (Bales 1950), see Appendix K.3
PCS = Participation Analysis Coding Scheme, see Chapter 3
RCA = Relational Communication Analysis, see Appendix J.4

2.3.3 Interaction as Action

The action perspective views interaction as task, coordination, production, and goal-oriented and teams make contributions to meeting tasks, the goals and strategies of the process, production of the project artifact and project goals. I identified four concepts that researchers commonly examine in relation to the action-oriented perspective: doing, coordinating, producing, and acting.

Doing. All teams *do* something (McGrath 1984). I interpret the concept of "doing" in relation to whether the team is doing project-related activity. Many of the studies that examine some aspect of action distinguish between task- or project-related activity and non-task non-project-related activity (Bales 1950; Olson et al. 1992; Poole & Roth 1989b). Interpretations of the nature of what teams are doing, though, vary significantly. Poole and Roth, for example, develop a coding scheme to describe the process of decision-making and center the process around decisions. Olson et al. (1992) make distinctions relative to the collaborative design process and center the process on issues. These studies make assumptions with respect to the focal nature of activity. I build on the Olson et al. (1992) issue-centered approach since it applies generically to design, engineering, and review meetings. Olson et al.'s scheme, Collaborative Design Workflow (CDW), comes closest to making distinctions between different task-related project interactions and applies broadly to a variety of project meetings.

Coordinating. In the action perspective of this work, the coordination-oriented view examines interaction as the process of coordination and facilitation. Malone and Cranston (1994, p. 87) define coordination as the "process of managing dependencies among activities." A closely related concept is facilitation—the planned intervention and modification of meeting interaction (Hirokawa & Gouran 1989; Bostrom et al. 1993; Gladstein 1984). Several studies cite a relationship between coordinating and outcomes and attribute the relationship to the type of task the team is performing (Bales 1976; Hirokawa & Gouran 1989). Multiple studies examine some aspect of coordination using observational data, including Bales (1950), Olson et al. (1991), and Futoran et al. (1989). Steiner's theory of productivity (Formula 2-7) examines the group process as a function of coordination. Thus, coordination is a key aspect of team interaction and may be examined at the process level through interactions that facilitate or coordinate project resources, meeting process, or participation of meeting participants at the interpersonal interaction level.

Producing. In the action perspective of this work, the production-oriented view examines interaction in relation to the production of something, e.g., an artifact, which can be tangible like a drawing or intangible like a discussion elaborating a design idea. The concepts of productivity, performance, etc. are associated with this perspective. As noted earlier, meetings typically do not have tangible outcomes. Most studies rely on tangible outcomes or develop project-specific measures such as number of ideas or agenda items that are addressed (Gallupe et al. 1992; Garcia et al. 2003b). If we use the concept of shared model or the "object world" we can conceptualize the meeting process in relation to producing that model. Goldschmidt (1995, p. 195) enacts this conceptualization and defines a *move* as "a step, an act, an operation, which transforms the design situation relative to the state in which it was prior to that move." *Links* are relationships between moves. Goldschmidt used the concept of moves and links to operationalize a definition of design productivity. Moves with a higher number of links indicate higher design productivity. Kan and Gero (2004) apply these concepts using linkography to visualize the relationship between these moves and topics. This is one way to examine interaction relative to the production of the project artifact. Many coding schemes include categories that distinguish between activity that "grounds" to those that "produce" using labels such as "elaborate", "generate", and "alternative" (Liston et al. 2001; Olson et al. 1992; Poole & Roth 1989a).[5]

Acting. In the action perspective of this dissertation, acting is the process of resolving, making a decision, or committing to resolve an issue. It is goal-oriented, but does not necessarily result in the production of something tangible. Many studies include codes that distinguish between other aspects of communication and action and the explicit process of acting. Some solely interpret action as the process of making a decision, whereas others, such as RCA interpret action as responding adequately. I elaborate upon

[5] Throughout Chapters 2-5, I compare and use original codes and labels from prior coding schemes, so there are style differences. Some of the labels are the base form of the verb, such as "explain", others are the present participle, e.g., "explaining", and some are a noun or adjective, e.g., "alternative".

these notions with the concept of commitment. Commitment refers to the process of confirming how an issue will be resolved and committing to resolving it. This concept is similar to the closed-loop communication concept discussed in Section 2.3.1. It distinguishes the overt act of communicating resolution particularly in contexts when the information is not available or further communication is necessary. I found that simply analyzing interaction in terms of making decisions did not meaningfully distinguish team interaction. I observed differences in how teams address issues that could not be resolved in the meeting and the commitment aspect of those communications potentially captures those differences.

Some action-oriented studies and associated coding schemes capture all of these action orientations and all capture at least two of these orientations. A formalized model of action based on prior research is in Formula 2-11. Table 2-4 summarizes the concepts and constructed related to the action perspective of team interaction.

Formula 2-11: Formalization of the action process combining the task, production, goal-oriented views of interaction.

$$action\ process\ =\ A = \{doing, coordinating, producing, acting\}$$

Table 2-4: Summary of review of concepts and constructs related to conceptualization of interaction as action. Chapter 4 further analyzes the bold coding schemes.

Action Perspective of Interaction					
Level of Analysis	Conceptualization	Process Concept	Questions	Why examine the process?	Coding Schemes
Project	goal-oriented	acting	Is team acting on a project issue?	Do differences in number of issues addressed or resolved relate to differences in media use?	**DFCS, RCA**
		producing	Is team producing something?	Do differences in production of ideas, problems, etc. relate to differences in media use?	**CDW**
Process	process-oriented, make contributions to process flow and structure	coordinating	Is team coordinating, facilitating, or managing meeting process? Is team maintaining the flow?	Do differences in facilitation relate to differences in media use? Do differences in the rhythm or pace of the meeting relate to differences in media use?	**GWRCS**, **CDW** TEMPO
Interpersonal Interaction	task-oriented, make contributions to accomplishing tasks	doing	Is activity project-related? If so, is it issue or task-oriented? Past or future-state oriented?	Do differences in focus relate to differences in media use?	**CDW, DEEP, POP**

CDW=Collaborative Design Worfklow (Olson et al. 1992), see Appendix K.1
DEEP = See Appendix K.6
DFCS = Decision Function Coding System (Poole & Roth 1989), see Appendix J.2
GWRCS = Group Working Relationship Coding System (Poole & Roth 1989), see Appendix J.3
IPA = Interaction Process Analysis (Bales 1950), see Appendix K.3
POP = Product, Organization, Process (Fischer and Kunz 2007)
PCS = Participation Analysis Coding Scheme, see Chapter 3
RCA = Relational Communication Analysis, see Appendix J.4
TEMPO =Time-by-Event-by-Member Pattern Observation (Futoran et al. 1989)

2.4 Approaches to Describe and Compare Media Use

The study of media use in the organizational context emerged in multiple disciplines in parallel with the study of teams including Management and Organization Science, Small Group Research, Workplace Studies, Design Studies, and Human-Computer Interaction. These studies attempt to answer a wide array of

research questions related to media use: *Why do teams choose different media? Are different media suited to different tasks? How does media use differ from intended use? What organizational changes occur when using new media? How do people use media?* Answers to such questions have led to several seminal theories, conceptual frameworks, and narrative descriptions of media use. I build on concepts from Media Richness Theory, the "emergent" model of media use, and enactment model. I identify concepts that described "nuances" in my observations of media use, relying more on empirical analysis and drawing upon the research to confirm or cite sources for those differences.

2.4.1 Models of Media Use

The early models of media use focus on the process of choosing media as opposed to using media. Media Richness Theory (MRT), for example, posits that media differ in information richness—"the potential information carrying capacity of data" (Daft & Lengel 1984, p. 7). The dimensions of information richness are a function of inherent static properties of the media: the feedback capability, communication channels, source, and language of the media. MRT posits that different organizational tasks, in terms of equivocality and uncertainty, fit different media (Figure 2-6[A]). Most researchers invoke this conceptualization of media use to identify media that fit different types of organizational tasks. Such approaches assume that media use is constrained by the inherent media properties and not influenced by differences in users or environment. This conceptualization, though, is sufficient to describe differences in media use. For example, media use at a given time can be defined in terms of the source, feedback, modality, and content. Most researchers invoke this conceptualization of media use to compare and differentiate media. I found this conceptualization well suited to describe properties of media use for a specific interaction (Formula 2-12). For example, media use at a given time can be defined in terms of the source, feedback, channel (modality), and language (content).

Formula 2-12: Formalization of a model of media use based on Media Richness Theory.

$$media\ use\ process = M = f(source, feedback, channel, language)$$

This conceptualization of media use does not account for the different ways teams utilize media. As I noted earlier, teams may use the same media but vary significantly in the extent to which they use the media or how they use the media. Barley's "technology-triggered" perspective examines the effects over time of different *media use* on organizational structure (Barley 1986). Barley's study, for example, showed the potential of technology to change how teams behaved and functioned by comparing the introduction of CT scanners in two hospitals. The study showed differences in how those teams implemented the media and specifically in the change to organizational structure that occurred through media use. Figure 2-6(B) conceptualizes Barley's "technology-triggered" model—how media changes organizational structure or "rules and resources provided by technologies and institutions as the basis for human activity" (DeSanctis and Poole, p. 24). Formula 2-13 formalizes the technology-triggered model.

Formula 2-13: Formalization of a model of "technology-triggered" media use that accounts for the role of the team's structure on media use.

$$media\ use\ =\ M = f(organizational\ structure, media\ properties)$$

DeSanctis and Poole (1994) examine the mutual interplay of technology and organization in Adaptive Structuration Theory (AST). AST posits that media vary in their features and spirit and these structures encourage different interaction. In turn, organizations vary in structure and this affects media use. AST further posits that media structures and organization structures emerge through the "appropriation" of these structures (DeSanctis & Poole 1994). Markus and Robey (1988, p. 588) refer to this as the *emergent* perspective and "that the uses and consequences of information technology emerge unpredictably from complex social interactions." The AST model comes closest to capturing a model of interaction that examines interaction from two distinct perspectives and examines the dynamic relationship between media use and team interaction. It was influential in sharpening my perspective of meeting interaction and conceptualizing a model of interaction from two distinct analytic perspectives. AST focuses on the "structuration" process whereas the focus here is on the communication, action, and reaction processes (Figure 2-6[D]). It also conceptualizes media as a single technological system and is inadequate to study multiple media.

Formula 2-14: Formalization of the "emergent" model of media use based on Adaptive Structuration Theory (AST). AST conceptualizes the interaction process as the mutual processes of team interaction and media use, and in turn, outcomes are a function of these processes and environmental factors, such as task, team make-up, and media features.

$$I = \{T, M\}$$
$$interaction\ process\ outcomes\ =\ f(T, M, E)$$

where:

$$media\ use\ =\ M = \{appropriation, instrumental\ use\}$$
$$E = \{task, organizational\ structure, media\ structure, media\ spirit\}$$

AST is one of the few examples of a model of media use and interaction that includes operational definitions. DeSanctis and Poole (1994) operationalize the AST constructs using a coding scheme and demonstrate its use for micro-level analysis of meeting interaction. The coding scheme comprises some 23 categories and its categorical distinctions are esoteric and difficult to discern. One category of analysis that influenced this study is the concept of instrumental use. AST distinguishes the purpose of media use to support task, process, social activities from purposes that are for fun and exploration. I found this analytic perspective valuable in distinguishing differences in media use and examine "purposing" as a fundamental aspect of the media use process. DeSanctics and Poole demonstrated the concepts of AST at a micro-level of analysis for a small set of interactions. They demonstrated its power at a macro-scale to compare the implementation of technology in three separate case studies. In this dissertation, I explore the "emergent"

perspective at a micro-level of analysis to identify patterns of mediated interaction (Figure 2-6[D]) that emerge and recur within small time frames.

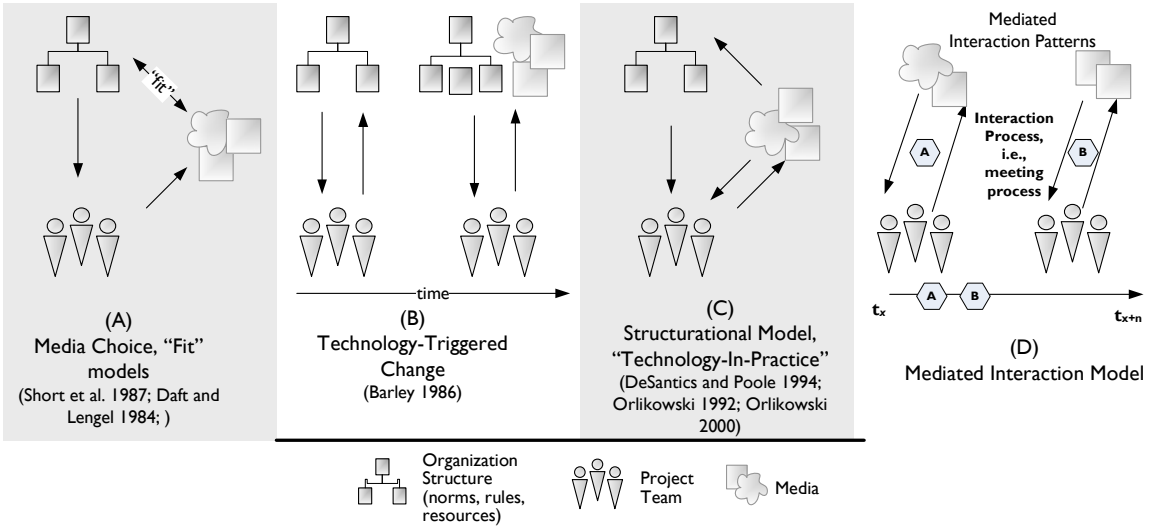


Figure 2-6: Comparison of models examining interplay of media use and team interaction developed based on macro-level analysis of teams in organizations and differences in the role of media use in organizational or team behavior, e.g., structure, choice (adapted from Orlikowski (1992)). (A) The Media Choice or "fit" models examine properties of media that fit organizational tasks (Daft and Lengel 1984; Short et al. 1976); (B) Technology-triggered change examines how changes to organizational structure occur through media (technology) use over time (Barley 1986); (C) Structuration models examine the mutual interplay of media on organizational structure at a micro and macro-level; (D)The Mediated Interaction Model (MIM) developed in this dissertation (see Chapter 4).

Also influential to my approach is the "technology-in-practice" model of enactment that uses the emergent model to describe and identify patterns of media use in relation to process changes (Orlikowski 2000). Orlikowski describes three types of enactment: inertia, application, and change. *Inertia* refers to situations where media use is limited and the process remains the status quo. *Application* refers to patterns of using media to collaborate, produce, solve problems, and the media use enhances current processes. *Change* refers to patterns where media use leads to improvisation and changes status quo process. Orlikowski does not operationalize these concepts using observational data. I build on Orlikowski's approach to describe patterns of interaction at a micro-level of analysis—as a function of media use and interaction—and to compare them relative to status quo interaction and not to idealistic interaction.

Formula 2-15: Formalization of the "technology-in-practice" model of enactment based on (Orlikowski 2000). A pattern of interaction, P, or as Orlikowski refers to it, "enactment" is referenceable in terms of the level of media use and the change, Δ, in interaction relative to "status quo" interaction.

$$pattern\ of\ media\ use = P = f(level\ of\ media\ use, change\ in\ interaction)$$

In this dissertation, I identify similar patterns of enactment at a micro-level of analysis. Many researchers share the view that the way teams use media, particularly in a design and engineering context, is a critical and essential aspect of how projects are realized. Bly (1988, p. 255), for example, notes that "the actions, uses, and interactions on a drawing artifact (surface) are as important to the effectiveness" of

the collaboration as the final artifact produced (Greenberg et al. 1993). Multiple researchers make similar evaluations of the role of media in team activity (Bucciarelli 1984; Henderson 1991, 1998; Luck 2007; Whyte et al. 2007). These studies give credence to my approach and enlightened my view of media use in the engineering and design context.

2.5 Concepts and Constructs to Describe and Compare Media Use

These models of media use inspired my approach but lack a coherent framework or set of concepts to describe differences in how teams use media. I identified three aspects of media use from the observations and literature that describe differences in how teams use media: use, interactivity, and purpose. I examine two aspects of use: utilizing and accessing. I discuss these concepts, their relevance to describing and comparing media use, and point to examples of their use in prior studies. I conclude the section with a conceptual model of media use that integrates these concepts. Here, I focus on the theoretical concepts and emergence in the literature. Chapter 4 further elaborates these concepts, particularly with respect to the different levels of analysis, through a comparative analysis of coding schemes that operationalize these concepts.

Utilizing. Media use varies in frequency, amount, and type of media use. The Case Examples demonstrate meeting interaction involving no media use to constant media use, and use of a single media to multiple media. Surprisingly, few studies examine any of these aspects or pose the simple analytic question, "Is the team using media, and if so, what type?" Most studies assume *use*. Many meetings I attended involved media that the team did not use. In other meetings, the team used the media frequently and used multiple media. Accounting for these differences seems essential if we are to understand how teams use media. Only a handful of studies, though, examine these aspects of media use. For example, Stephens (2005) examines differences by type, frequency, and combination at a macro-scale. Stephens examined the frequency of sequences of media use, such as Web then Face-to-Face (FtF). Yet, no study has examined sequences of media use by type in meeting context. Covi's (1998) study of workspaces describes the different type of media available in different rooms but does not discuss the frequency or use of those media. Tory et al. (2008) label different interactions with respect to the type of media the team interact with, but do not use that observational data to describe patterns of use or measure amount or frequency of use. An operational definition of utilizing is dependent on identifying whether or not a specific interaction involves the use of any media and if so, what type of media.

Accessing and Transitioning. Media use varies in accessibility and the frequency and type of transitions. The Case Examples demonstrate use of shared media as well as use of only private media or media accessible to only a single participant. Examining this aspect of media use tells us, what, if any differences in access play a role in team interaction or whether transitions between different media affect team interaction. Many of the conceptualizations of media use limit the focus of analysis to a single medium and a single user excluding the spatial aspect of media use. Workplace and Design studies make particular note of the effects of the physical environment on interaction. Heath and Luff (1992, 2000, 2004) describe the role of the physical workplace and use terms such as "publicly available media", "semi-

shared" displays, and "private media" to distinguish differences in interaction with media available to the group (Heath et al. 2000; Luff et al. 1992; Luff et al. 2004). Tang (1989) notes the effect of location of media on interaction and discusses differences in when users share media on a table compared to when users interact with a whiteboard. Tang identifies three characteristics of use: orientation, proximity, and simultaneous access. Streitz et al. (2005) refer to these labels as "accessibility" of media. Other labels include "intimate", "social", "personal" in reference to the availability and proximity to media (Nova 2003; Shen et al. 2003). I use the term accessibility to refer to the extent to which a medium is available to all participants in a meeting space.

Several studies cite the effects of accessibility of media on team interaction (Hawkey et al. 2005; Nova 2003; Spinelli et al. 2005). For example, Hawkey et al. (2005) compare collaborative settings where both group members are near a display, far from a display, and one is near and one is far from the display and report more satisfaction when both members are near the display. They describe situations when "communication breakdowns" occur in the near/far scenario. Hawkey also notes that teams make fewer gestures or annotations when they are not near a display suggesting that participants are less likely to interact or participate if the media are not accessible. In the meeting context, accessibility of media is dynamic. As the team moves its focus from one medium to another medium, changes in accessibility may occur.

Another aspect of media use in a multiple media context are the transitions that take place between media. Tang et al. (2006) note the effects of the physical transitions in media workspaces in a study of teams using multiple media. Bélanger & Watson-Manheim (2006) look at transitions from one medium to another at a macro-scale to support various communicative activities. This aspect of media use in a meeting context is largely unexplored and no studies operationalize the access or transition concept using observational data.

Interacting. Media use varies in the physical and cognitive way in which teams interact with the media. In the Case Examples, some teams are physically engaged with the media through a variety of gestures, whereas other teams indirectly interact with the media. Describing differences in "interacting" tells us whether features of the media or how teams can interact with media play a role in team interaction. Do teams interact differently with different media? And does that relate to differences in team interaction?

The concept of interactivity has multiple conceptualizations. Here, I use it not as a property of the media but as a feature of the interaction with the media. For example, Steur (1995, p. 84) defines interactivity as "the extent to which users can participate in modifying the form and content of a mediated environment in real-time." Burgoon (1988, p. 660) describes differences in interactivity in terms of the degree of involvement and behavioral engagement with the media. Both of these characteristics of interactivity suggest that there are different levels of interactivity and behaviors associated with interacting. That is, one can describe how teams interact with media as a function of different levels of engagement with media, indirectly and directly. Tory (2008, p. 325), for example, defines interaction as "cognitive and

physical engagement with artifacts; in other words, the active use of artifacts." I ascribe different media use behaviors to meeting interactions that distinguish between different levels of engagement.

The research by Clark and Brennan (2003; 1991) on pointing and communication was influential to examining this aspect of media use. Similar to human-human communication, teams use verbal and physical gestures such as pointing to anchor communication. McNeill (1992) refers to this as a "deictic reference" or the practice of pointing, looking, touching or gesturing to indicate a nearby object mentioned. Clark (2003) distinguishes between two types of physical gestures, "directing to" and "placing for", that act as "attention-directors." Several studies build on these concepts and look at discrete types of interactivity, for example, gestures or motions, and their relation to media and interaction. For example, Bekker et al. (1995) examine the "rich array of traditional media" teams use, including whiteboards, drawings, lists, etc. Their research study examines how teams interact with those media and suggests a typology of interactions using speech and gestures (kinetic, point, spatial, other). They compare different gestures and the purpose of those gestures to support design communication, to manage the process, and support the conversation, but Bekker et al. do not associate the use of gestures with outcome or process factors. Bekker et al. identify patterns between the process of generating design ideas and to differences in physical actions with media. Tang (1989) distinguishes between three physical types of interactions, "list", "draw", and "gesture". Tory distinguishes nine types of gestures teams use to interact with media, such as "five-finger pointing" and "parallel indication". Like Bekker, Tory identifies patterns of interaction but does not describe differences in use across meetings or relate those differences to differences in team behavior. Chapter 4 develops a coding scheme that draws upon those developed by Clark (2003), Tory (2008), Bekker (1995), and Tang (1989) to describe differences in "interacting".

Purposing. Many of the frameworks and coding schemes that examine an aspect of media use distinguish differences in the purpose of media use or its "instrumental purpose" (DeSanctis and Poole 1994). Some distinguish the purpose relative to a specific communication purpose. Bly (1988), for example, compares different uses of a drawing surface by two-person groups, using a simple taxonomy: "illustrate", "reference", and "note." Others describe purpose in relation to their role as artifacts of knowledge. For example, Bechky (2003), Carlile (2002), and Star (1989) use the concept of "boundary" objects to describe how engineering drawings mediate relations and act as sources of knowledge. Henderson (1999) describes the role of artifacts as "conscription devices" unfolding in time in terms of their communicative content. These two views describe the dual purpose of media as objects of knowledge and as devices to communicate, capture, and generate project information. Hendry (2004) builds on these concepts and proposes five "communication functions" of project artifacts: conscripting, coordinating, framing, persuading, and recording (Hendry 2004). My prior research developed a coding scheme, DEEP (see Appendix K.6), that examined the purpose of media use relative to project information and proposed four functions of media use: describe project information, explain, evaluate, and predict. These various perspectives share similar concepts. These studies do not examine how purpose changes in moment-to-

moment interaction or in relation to team interaction. I incorporate both perspectives of media purpose in my analysis of media use.

Table 2-5: Summary of concepts associated with aspects of media use, their relevance with respect to analytic and research question, and coding schemes that operationalize these concepts. The bold coding schemes are included in the comparative analysis in Chapter 4.

Media Use Processes				
Perspective	**Processes**	**Analytic Questions**	**Why examine the process?**	**Coding Schemes**
use	utilizing	Is the team using media? If so, what type?	Do differences in frequency and use of different media play a role in team interaction?	
	accessing	Is the team using media, accessible to one, some, or all meeting participants?	Do differences in how teams access media play a role in team interaction?	(Nova 2003), (Shen 2003)
	transitioning	Is the team transitioning from one medium to another?	Do transitions between media play a role in team interaction?	
interactivity	interacting	Is the team physically or cognitively interacting with the media? How is the team interacting with the media? What is the level of engagement with the media?	Do differences in how teams physically interact with media play a role in team interaction?	**(Tory 2008) (Clark 2003), (Bekker 1995) (Tang 1989)**
purpose	purposing	What is the instrumental purpose of the media use?	Do differences in the instrumental purpose of media play a role in team interaction?	**AST (DeSanctis and Poole 1994), DEEP (Liston et al. 2001) FWA (Tang 1989) (Hendry 2004)**

AST = Adaptive Structuration Theory, see Appendix J. 1
DEEP= see Appendix K.6
FWA = Framework for Analyzing Workspace Activity, see Appendix J.7

In summary, the assumptions of my approach related to media use are:

(a) Meeting interaction (*I*) is the mutual interdependent processes of team interaction (*T*) and media use (*M*) (Orlikowski 1992; DeSanctis and Poole 1994; Orlikowski 2000) (Formula 2-17). This conceptualization, at a high-level, is no different from DeSanctis and Poole's conceptualization in AST, but the components of *T* and *M* are different. That is, I examine different aspects of the team interaction and media use processes.

(b) The media use process comprises three interdependent processes: use, interactivity, and purpose (Formula 2-16).

(c) Differences in media use processes occur in relation to the systems within which teams interact and use media: to the project, meeting process, and interpersonal interactions.

I formalize this conceptualization of media use in Formula 2-16. Chapter 4 further elaborates this model and operationalizes these concepts using video-recorded observations of meetings to interpret and analyze behaviors associated with the media use processes. Note that this conceptualization of media use examines two of the characteristics of media that Media Richness Theory examines. "Utilizing" relates to the concepts of source, channel, and language and "interacting" relates to the concept of feedback. This

conceptualization, though, is markedly different from AST, with the exception of examining "purposing". Chapter 4 elaborates this discussion with respect to application of the AST coding scheme to a sample of meeting observations. The concepts that AST examines, such as appropriation, spirit, and structures, are difficult to interpret in meeting interaction and in multiple media contexts. The processes that I examine broadly apply to a variety of media and meeting environments. It combines the physical aspect of media use, which MRT and AST do not, with the instrumental purpose of the media use.

Formula 2-16: Formalization of a model of media use synthesizing prior models of media use. The model

$$M = \{use, interactivity, purpose\}$$

2.6 A Model of Mediated Interaction

I propose a model of meeting interaction that synthesizes and builds on prior approaches to study the relationship between how teams interact and use media in AEC project meetings. I refer to this model as the Mediated Interaction Model since it conceptualizes meeting interaction as two interdependent processes of team interaction, *T*, and media use, *M* (Figure 2-7). MIM further decomposes the team interaction process into the three interdependent processes of communication, *C*, reaction, *R*, and action, *A* (Formula 2-17), each of which are further decomposed into a set of processes (Figure 2-7) based on this literature review and further analysis in Chapter 4.

Formula 2-17: Formalization of a Mediated Interaction Model (MIM) of interaction combining the systematic methods, multi-purpose, and multi-level perspectives of interaction.

$$Meeting\ Interaction\ Process\ =\ I\ = \{T, M\} = \{C, R, A, M\}$$

where I is a sequence of meeting interactions from 1 to N, where N represents the total number of meeting interactions:

$$I = \langle i_1, \ldots, i_N \rangle$$

$\langle . . \rangle$ are symbols for a sequential set.

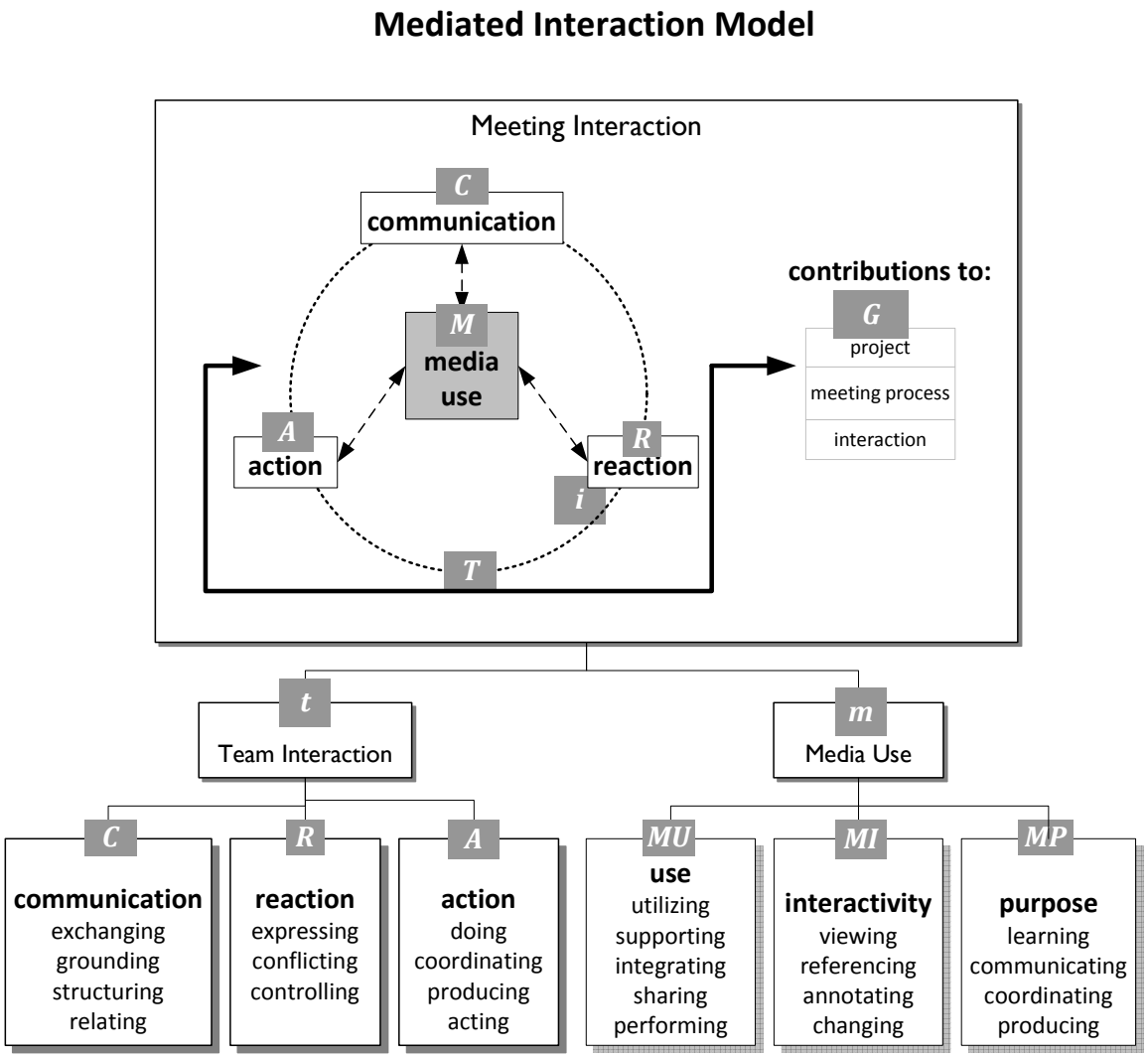


Figure 2-7: Mediated Interaction Model (MIM) of interaction process. MIM conceptualizes interaction as a set of four interdependent processes: communication, reaction, action, and media use that make contributions to three systems: the project, meeting process, and interpersonal interactions. The model conceptualizes these as process gains and losses. Chapter 4 extends the discussion of these concepts and rationale for examining these processes.

The team interaction processes make contributions, *G*, to three systems:

(a) project, i.e., to artifact production and project goals

(b) meeting process, i.e., contributions to meeting process tasks and maintaining process flow,

(c) interpersonal interactions, i.e., relational communication between meeting participants, and exchange of project information between meeting participants.

MIM conceptualizes these contributions as moment-to-moment gains and losses to these systems (Formula 2-18).

Formula 2-18: Formalization of a model of interaction combining the systematic methods, multi-purpose, multi-level, and process gains and losses.

$$G = f(C, R, A, \mathrm{M})$$

$$Contributions\ of\ Meeting\ Interaction\ Process = G = \sum_{\mathrm{n}=1}^{\mathrm{n}=\mathrm{N}} G_{\mathrm{n}}$$

where G_{n} represents the contributions of the nth meeting interaction, i_1, to the project, process, and interpersonal interactions:

$$G_{\mathrm{n}} = G_{project} + G_{process} + G_{interpersonal\ interactions}$$

MIM is most similar to McGrath's conceptualization of the interaction process, but extends that model to include the process of media use. MIM assumes that the process of media use is integral to meeting interaction and that team interaction is closely intertwined with media use in AEC meeting interaction. MIM is not a contingency model and does not examine the causal relationship between inputs and outputs. MIM removes the dependencies on inputs or outputs to examine the relationship between interaction processes in meeting interaction. MIM breaks apart the meeting interaction process into discrete meeting interactions, each of which are analyzable with respect to a) the MIM processes and b) the contributions the interaction make to the project, process, and interpersonal interactions. A sequence of these interactions that recur within meetings or in multiple meetings constitutes a pattern of mediated interaction (Formula 2-19).

Formula 2-19: Formalization of a pattern of mediated interaction.

$$pattern\ of\ mediated\ interaction = P = \langle i_p, \ldots, i_q \rangle$$

such that *P* is a subset of *I:*

$$P \subseteq I$$

The remainder of this dissertation uses MIM as a basis to examine the relationship between team interaction and media use and provide evidence for MIM and the "reasonableness" of its assumptions. Chapter 3 discusses the research methods employed to operationalize its concepts. Chapter 4 compares prior coding schemes that operationalize one or more of the MIM concepts and develops a coding scheme to interpret and code all the key aspects of team interaction and media use conceptualized and formalized in MIM. Chapter 5 operationalizes the two main constructs—team interaction and media use—using the results from Chapter 4 and integrating the concept of contributions formalized in Formula 2-18. Chapter 6 operationalizes Formula 2-19 using the results and findings from Chapters 4 and 5.

Chapter 3: Research Methods

"Validity is not a commodity that can be purchased with techniques. . . . Rather, validity is like integrity, character, and quality, to be assessed relative to purposes and circumstances." (Brinberg and McGrath, p. 13)

"As observers and interpreters of the world, we are inextricably part of it; we cannot step outside our own experience to obtain some observer-independent account of what we experience. Thus, it is always possible for there to be different, equally valid accounts from different perspectives. (Maxwell 2002, p. 41)

3.1 Introduction to Research Methods and Tasks

Validity in qualitative research and social science research addresses the quality of the research and whether the researcher's construction of the social world is plausible and the methods to reconstruct the social world are reliable. Some view validation as a "craft" and a process of "checking, questioning, and theorizing on the nature of the phenomena investigated" (Kvale 1995). The issue of validity in social science is multi-dimensional and complicated by the differing paradigms underpinning various methods (Seale 1999; Maxwell 2002; Sale et al. 2002). How researchers validate their research reveals their view of the social world *and* the quality of their work. I took the advice of Seale (1999) to develop my "own style" mixing qualitative and quantitative methods, grounded research and interaction analysis methods. In essence, this reflects my multi-dimensional perspective of meeting interaction.

I faced two significant methodological and validation challenges with my mixed-method approach. First, existing observation-based methods to interpret and analyze micro-level interaction rely on descriptive methods of analysis that do not integrate multiple perspectives and miss the temporal aspect of interaction. To address this challenge, I had to develop my own observational analysis methods. Second, validating social science research often uses existing constructs for comparative purposes to test the validity of a construct. However, the constructs I developed are multi-categorical and measure aspects of team interaction previously not measured in a single construct. To address this challenge, I rigorously reported my methods, assumptions, and rationale for the operational definitions of those constructs.

The constructs and operational definitions to describe team interaction and media use emerged over a period of ten years and four distinguishable phases. In each research phase I iteratively observed, coded, analyzed, developed, and refined the constructs and methods (Figure 3-1). Each phase represents differences in methodological approaches, moving from unstructured, qualitative methods using a single construct to structured, quantitative methods using multiple constructs; and emergence and refinement of the constructs, research methods, and the visualization methods I developed to describe and compare meeting interactions.

This chapter begins with an overview of observational, coding, and analytic methods I used in the research. This overview serves three purposes. First, it reports my research methods. In social science, it is essential to report the research process and the assumptions made in the selection of methods. Second, it provides accounts of existing research methods to describe and compare meeting interaction using data in

this research. Jordan and Henderson (1995) suggest that it is often impossible to separate the method from an account or example of the method. Thus, I include examples that potentially warrant further explanation with respect to content, but are included to demonstrate specific methods. Third, it serves as more detailed background about existing research methods to (a) operationalize the team interaction and media use constructs (introduced in Chapter 2) using observational data, (b) describe observations using those constructs, and (c) compare interaction using those constructs. The chapter concludes with a summary of my validation methods to provide readers with information to assess the quality of the findings and the proposed approach.

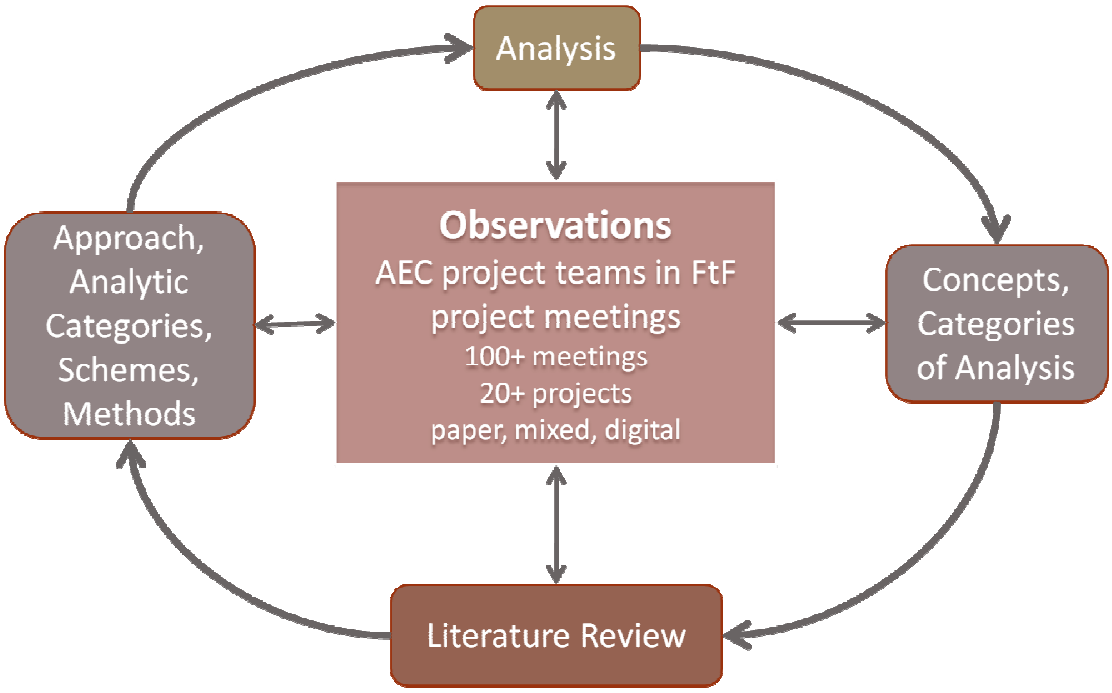


Figure 3-1: Diagram showing the iterative research process centering on observations of AEC project meetings and involving construct and category development, literature review, development, and refinement of the analytic framework and proposed approach, and analysis.

3.2 Observations: Scope and Data Collection Methods

Observing people in natural settings has a long history in the social sciences and qualitative research. Branches of qualitative research include ethnomethodology (Garfinkel 1967), case study methods (Eisenhardt 1989), and grounded research (Glaser and Strauss 1967; Corbin and Strauss 1990). Methods vary in: 1) role of observer, 2) number, frequency, and length of the observations, and 3) methods of data collection. My observer role varied from participant observer to indirect observer via video recordings. Observations were more frequent in the early phases of the research, and data collection evolved from informal, unstructured observations to formal, video-recorded observations and collection of satisfaction data via a post-meeting survey (Appendix D).

I observed over one hundred multi-disciplinary AEC project meetings on twenty different projects ranging from conceptual design to construction review meetings. The meetings varied in nature, length, number of attendees, media available, and location, as summarized in Table 3-1. Meeting selection

depended on opportunity, access, and media format to balance the observation data between digital, mixed, and paper media and across project phases. As discussed in Chapter 2, the focus of observation was on the "team" and not individuals and on the process and not on contextual data. I did not formally collect any contextual data. I only observed meetings involving multi-disciplinary and multi-organizational teams. I informally collected data such as team make-up and contractual work relationship, whether the team was co-located or distributed, experience of the team as it relates to the media environments, and overall project issues. I refer to these data in the discussion sections and in some of the narrative discussions of the examples. The following three sections discuss the different observer roles and different data collection methods by research phase.

3.2.1 Phase I: Participant Observation and Informal Data Collection

During Phase I, I worked on a single project for eighteen months, supporting the planning of a construction project. I attended on average two to three meetings per week, ranging from internal schedule review meetings to external meetings with the community, subcontractors, and AEC professionals. As a participant observer in numerous project meetings, I took notes and photos, and collected media samples, such as drawings, schedules, but did not video or audio record any meetings. The intensity, frequency, and number of meeting observations played a critical role in the motivation for this research and initial formulation of research questions and constructs to examine.

3.2.2 Phase II: Participant, Non-Participant Observations and Video/Audio Data Collection

During Phase II, I observed project teams as a participant and indirect observer and I video- and audio- recorded project meetings when possible. I observed several meetings as a project participant, but I also observed meetings as an indirect observer. As an indirect observer, I could focus on the interaction as opposed to worrying about personal project responsibilities. During this phase, I also enlisted a research colleague to record meetings on a project that I did some work on but was not directly involved in day-to-day activities. These multiple observer roles provided more observation opportunities and a broader set of observation data.

In Phase II, I performed a lab-based experiment to compare meeting interaction using paper to meeting interaction using digital media. In Chapter 2, I discussed the scope of the approach to study teams in natural settings based on characteristics of project teams. However, early in the research I considered complementing findings from the field with findings in the lab. The intent was to control the "media environment" and the "task." I created a mock-project meeting using real project data and enlisted four three-person student groups. The meeting goal was to choose a design option from three possible design options given a set of criteria, such as budget, schedule, and sustainability goals. I gave each group the same information using paper-based media or digital-based media. I created an interactive HTML questionnaire consisting of a set of questions to guide them through the design selection process. The questionnaire recorded the time spent on each task and their typed response. I video-recorded the mock meetings to analyze the interaction.

There were several challenges with this approach. First, it was difficult to form multi-disciplinary student groups with minimal domain expertise. Although teams in natural settings vary in individual expertise, it is rare to observe a meeting with only junior staff. All the students struggled with some of the basic concepts and questions and interpretation of drawings and figures. Second, the unnaturalness of the interaction resulted from the forced, one-time grouping. Although I never observed the same team (in exact makeup) more than once, all meetings included at least two to three members with prior experience working with one another. The student groups could not emulate project teams and their interaction did not sufficiently compare to the interaction I observed in the field. Due to these challenges, I focused solely on observing teams in natural settings in subsequent phases of the research.

3.2.3 Phase III and IV: IRB Protocol, Satisfaction Survey, and Additional Video Data Collection

One of the requirements when doing research with human subjects is following guidelines established by the Institutional Review Board (IRB). In Phase III, I applied for and received approval for an IRB Protocol titled "Observation of Information Use in Architecture, Engineering, and Construction Meetings on Building Projects" on 9/29/2006 and was re-approved on 10/25/07. The IRB consent form for this protocol, numbered 83461, is included in Appendix C. The IRB protocol mandated anonymity for all participants and that all participants submit consent to video recording orally or in writing. The video-recordings in Phase III and IV followed this protocol. I am indebted to the two organizations and three project teams that provided access and consented to the video recording of their meetings.

Several video-recordings took place prior to applying and receiving approval for IRB protocol. The IRB representative gave oral approval to include these in the study. These included (a) meeting video paid for by an AEC company, (b) meeting video of a public design charrette meeting, and (c) meeting video provided by a colleague at the University of British Columbia (UBC) following similar IRB protocols established by that university. The UBC team video recorded a project team over a six-month period. The difficulties in gaining access to meetings led to collaboration and sharing of meeting video. I visited the UBC project site, but I acted as an indirect observer of those meetings and I relied on the UBC team to provide any contextual data for those meetings. Tory et al. (2008) describe their observation and analysis of those meetings.

3.2.4 Data Collection Using Survey

Surveys are a common data collection method employed in field studies of teams. In many cases, surveys are the primary method of data collection. In Phases III and IV, I issued a satisfaction survey at the end of ten meetings to measure process and satisfaction outcomes. I adapted a survey developed by Briggs et al. (2004) to measure satisfaction in three areas: satisfaction with process, satisfaction with outcome, and individual perceived goal attainment. (See Appendix D for sample survey). I modified Briggs and Reilly's survey from its original 15 questions (five per satisfaction area) to nine questions (three per satisfaction area). This was in response to issues from early respondents about the repetitive nature of the questions and length of the survey. Briggs and Reilly validated their survey using factor analysis and Cronbach's alpha

for discriminant and construct validity. Cronbach's alpha is a measure to assess reliability of survey questions, particularly when several research questions measure the same construct (Cronbach 1951; Santos 1999). I also tested for discriminant and construct validity using Cronbach's alpha and the results indicate similarly high reliability measures as Briggs and Reilly. Appendix D discusses the survey results.

Table 3-1: Summary of observations performed throughout the four phases of the research. The table lists the quantity and number of those observations, location of observations, types of media available in the meeting, construction phase during which the meeting took place, and analytic schemes applied to those observations. The table shows the mixture of observation and data collection methods applied to meetings across phases of an AEC project using multiple types of media. The table also shows the evolution of the analytic schemes and the application of those schemes to observational data.

Phase	Observation Method				Data Collection					Location			Media Types		Project Phase		Analytic Schemes		
	Participant Observation	Direct Observation	Indirect Observation	Number	Notes	Photos	Audio Recording	Video Recording	Survey	Office	Onsite	Lab	Paper	Digital	Design	Construction	DEEP[a]	TEAM[b]	MIA[c]
Phase 1 18 months	■			40	■	■				■			■	■	■	■	■		
		■		6				■		■	■			■		■	■		
		■		4				■				■		■		■			
Phase 2 24 months	■			30	■	■				■	■		■	■		■			
		■		4				■	■	■			■		■		■	■	
			■	3				■			■			■		■	■	■	
		■		2			■				■		■		■	■	■		
Phase 3 4 years	■			10		■				■	■		■	■	■	■			
		■		2			■		■	■	■		■		■	■			
			■	10				■			■		■	■	■		■	■	■
Phase 4 2 years		■		3		■	■	■	■	■			■	■		■		■	■
Totals	80	17	13	110	70	83	7	30	9	95	63	4	~70	~40	~30	~80	12	3	9

[a] Media purpose coding scheme. See Appendix K.6.
[b] Team, Emotion, Action, Model Use coding scheme and framework. See Liston et al. (2007).
[c] Mediated Interaction Analysis coding scheme. See Chapter 4 and Appendix K.

3.2.5 Notes on Observations: Challenges with Video-Recording in Natural Settings

Video recording of teams in natural settings is an invaluable method but one fraught with challenges. First, it has to be pre-planned; yet much of the observation in natural settings and ethnomethodology is capturing events in everyday activity. This is why the unrecorded observations and extensive participant observation are critical to the development of concepts. Teams can behave differently in front of a camera, so I observed the teams off-camera when possible. Second, many teams do not want to be video-recorded, and the consent requirements mandated by IRB protocol added an additional layer of coordination to scheduling observations. Gaining access, scheduling, and getting consent proved to be difficult and greatly limited video-recorded sessions. Third, a single video recorder does not capture all meeting behavior, and

the audio recordings often miss talk in the background. I took notes during the observations, but there were periods in all meetings when I could not transcribe the verbal utterances.

Another challenge is the use of the survey instrument. Most of the meetings I attended ran over-time, team members arrived late and left early, and many had to leave immediately to go to another meeting. When teams did take the time to complete the survey, there were groups that openly discussed it and joked about it. I opted to exclude the survey data that met survey reliability standards but not my personal reliability standard. Given these challenges, only four out of ten meetings had reliable survey data and quality video-recorded data. I had quality video from an additional ten meetings with no survey data. Table 3-2 lists the meetings selected for the coding and analysis in the final phase. These challenges and feasibility of using surveys contributed to the development of an approach that is not dependent upon survey data. I use the survey data as a validation data point.

Table 3-2: Summary of observations selected for coding and analysis in last phase of the research. These meetings in several project phases represent a range of phases and media use. '■' indicates that the meeting had valid survey data.

Meeting	Meeting Type	Media Type	Meeting Duration	Percent coded	Total segments	Number of Participants	Survey Data
(E) Mtng 1	schedule review	digital	32	100%	188	15	
(F) Mtng 10	design	mixed	177	23%	296	15	
(G) Mtng 20	design	paper	109.1	34%	292	15	
(H) Mtng 30	design	digital	100	68%	567	12	
(D) Mtng 50	coordination	digital	103	100%	1070	12	■
(A) Mtng 60	concept	paper	31	100%	155	12	■
(I) Mtng 70	schedule review	mixed	62.5	100%	607	6	
(C) Mtng 80	coordination	mixed	109	100%	859	13	■
(B) Mtng 90	schedule review	paper	62	100%	725	8	■

3.3 Iterative Coding and Construct Development: Interaction Analysis

Coding is an essential step in transforming observational data, empirical or recorded, into theoretical (Glaser and Strauss 1967; Strauss and Corbin 1998), descriptive, or operational constructions of interaction processes (Glaser and Strauss 1967; Jordan and Henderson 1995; Strauss and Corbin 1998). Grounded researchers view coding as a means by which categories, concepts, or constructs *emerge* during the process of developing theory about social interaction. Interaction analysis researchers view coding as a means to apply pre-defined categories related to concepts and constructs to quantitatively describe and compare interaction processes. The coding methods employed here combine these approaches. Categories and concepts emerged from the observations, using open and axial coding methods common in grounded research. Concepts and constructs also emerged from applying pre-defined coding schemes developed by prior research and developed in this research using interaction analysis methods. The following discusses the contributions of both methods to this research.

Open coding is the "process of breaking down, examining, comparing, conceptualizing, and categorizing data" (Strauss and Corbin 1998, p. 60). Grounded researchers use memos or notes to highlight

when a phenomenon occurs and, through repeated observation of phenomena, translate a concept into categories. For example, in Phase I, which took place prior to the literature review, the initial research concept was "information focus" and how teams make decisions using information. As I observed meetings, I manually coded meeting notes to note when different information tasks occurred, and the following information tasks emerged: "describing", "explaining", "evaluating", and "predicting" (Liston et al. 2001). The second step in grounded research is axial coding to identify relationships between categories to develop theory. For example, I identified that the categories of "describing" and "explaining" relate to establishing a common ground whereas "evaluating" and "predicting" relate to decision-making and addressing project issues. Using these categories, I compared the extent to which different teams spent time "grounding" versus "acting". Unlike grounded researchers, I did not use the coding process to develop theory. Rather, I used open and axial coding solely as a means to develop concepts and categories to describe differences in team behavior and media use.

One of the concepts that emerged was the notion of the interplay of media use and team behavior and the recurrence of patterns of mediated interaction. Grounded research methods shun over-conceptualization of observations or detailed micro-level analysis (Glaser and Holton 2004). Interaction analysis (see Chapter 2 for introduction) explicitly examines the temporal aspect of interaction (Bakeman and Gottman 1986); (Jordan and Henderson 1995). The method of Interaction Analysis (IA) involves video recording "naturally occurring talk and activity" (Frohlich 1993, p. 1), and systematically coding the observed events to classify and quantify the interactions (Bakeman and Gottman 1986). These methods involve the categorization of interaction events such as utterances, speech acts, or non-verbal behaviors to produce numerical data and measures of the interactions. Researchers use IA to describe interaction processes, identify patterns of interaction, and compare different interaction processes.

IA, like content analysis, depends on concepts and foci of analysis. Researchers must still develop concepts and develop categories and related analytic schemes to apply those concepts to the observational data. Skeptics of IA argue that applying pre-defined categories limits the potential emergence of concepts, but IA researchers do not develop ad hoc coding schemes. Rather, the papers I reviewed by researchers employing IA fit one of two categories: 1) the iterative development and refinement of categories using established reliability methods, drawing upon literature, and first-hand observation or 2) applying or modifying prior coding schemes. This research uses both approaches and the following sections describe the IA process and methods used during Phases II through IV of transcribing, segmenting, coding, and assessing the reliability of the coding method and schemes. Figure 3-2 summarizes the different coding methods employed across the research in relation to the observations and evolution of concepts, categories, and constructs.

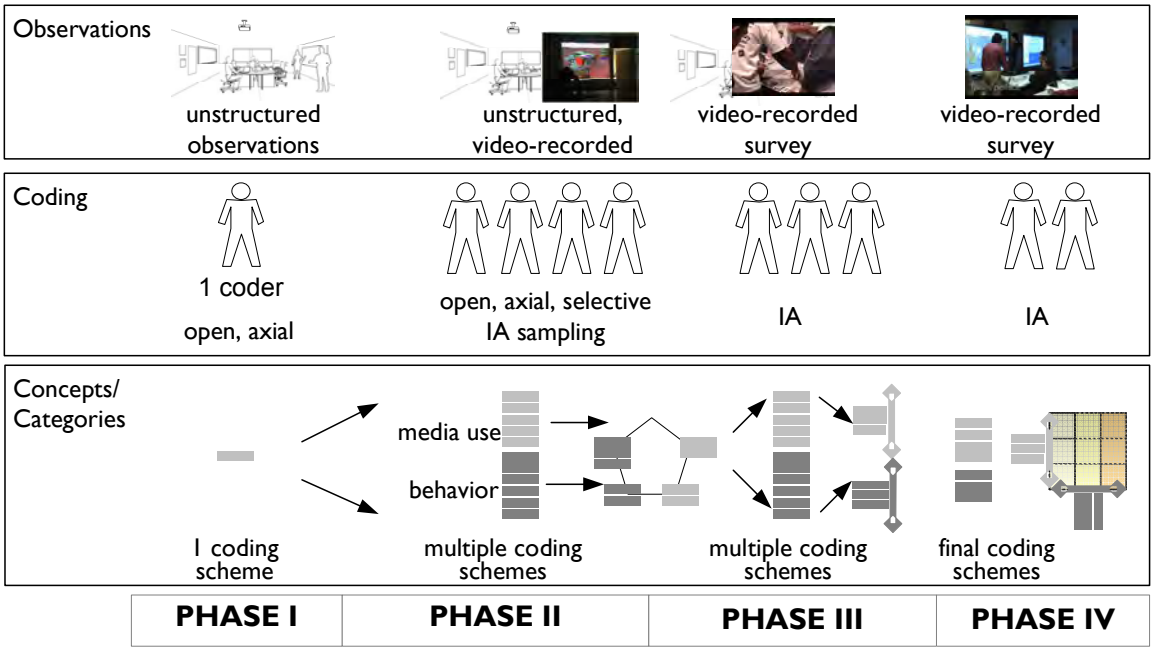


Figure 3-2: Summary of the coding methods by phase in relation to the observations, number of coders, and emergence and definition of concepts and categories. The coding scheme in Phase I is DEEP (see Appendix K.6). Chapter 4 discusses the coding schemes in Phase II, III, and IV.

3.3.1 Transcribing and Segmenting Observational Data

The transcription and segmentation process is a critical and time intensive step in interaction analysis. The researcher must select an appropriate level of analysis to capture the data at a level of detail sufficient to answer the research questions. The method must also ensure reliable coding across observational analysis data. In Phase I, I developed a protocol to segment and transcribe the video recordings. I developed the rigorous protocol described in the following paragraphs.

There are four common units of analysis used by interaction analysis researchers (Goffman 1981):

(a) *utterances or speaker turns*: This unit of analysis is defined as a "stretch of talk, by one person, before and after which there is silence on the part of that person" (Harris 1951, p. 14). The concept of utterance often refers to "speaker turns," and researchers segment talk when a new speaker takes the floor. This method of segmentation is the most common and widely used from researchers in communication studies, linguistics (Searle 1969; Allwood 1977; Carletta et al. 1997), design studies (Eris 2002), and AEC research (Garcia et al. 2003; Kan and Gero 2004).

(b) *thought ideas:* or "separable units of thought" (Siegel et al. 1986). Siegel et al. (1986) used this segmentation to segment transcripts of eighteen ten-minute verbal and computer-mediated exchanges between students.

(c) *time intervals:* This level of analysis is time-based and involves analyzing the observation at regular intervals such as 1 or 2 minutes (Bakeman and Gottman 1986); for example, Ward et al. (1995) used 30 second intervals and Nyerges et al. (1998) used one minute intervals, every two minutes.

(d) *counts:* This level of analysis "counts" discrete observed behaviors. For example, Adrianson and Hjelmquist (1991) counted words spoken by a participant, and Bekker et al. (1995) counted gestures.

Many researchers opt to define their own method of segmentation. Milne (2005), for example, defined segments as combinations of topic ideas and turns. Stumpf (2001) separated the transcript into "units" reflecting a combination of turns and utterances. Veinott et al. (1999) segmented first into speaker turns for one coding scheme and then into utterances for another coding scheme. I chose speaker turns to segment the transcripts and followed the definition of utterances to segment the data between periods of silence and between periods of parallel conversation when multiple participants were talking (overlap) (Jovanovic 2003). A segment represents a discrete meeting interaction, ***i***. In two meetings, several speaker turns lasted several minutes, and the topic or nature of the conversation changed considerably during a speaker turn. In such cases, I segmented those speaker turns into several segments to support more reliable coding of those interactions. Figure 3-3 shows an example of a transcript with speaking and non-speaking turns.

During the transcription process, I uniquely labeled each segment using an alphanumeric system. The first character, "A"-"Z," represents either a speaker or type of non-speaking category. I assigned each meeting participant a letter from "A"-"J." If I could not identify the speaker, I assigned the character "K" to the segment. If the segment represented a non-speaking time, I assigned one of the following three characters:

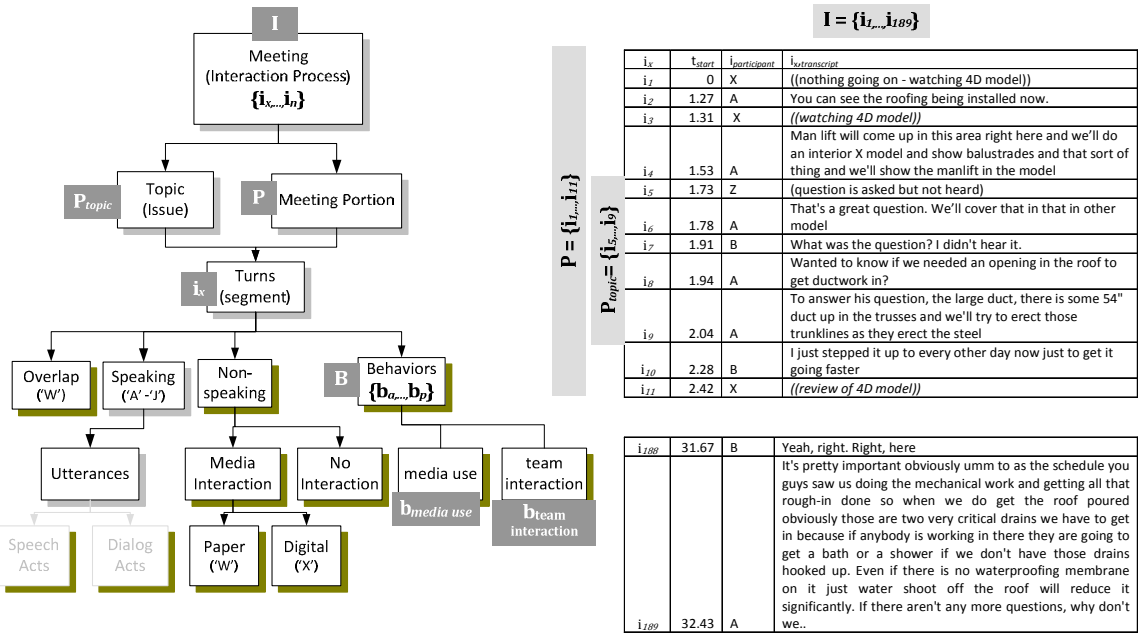
- "X": segment involving interaction with digital media.
- "Y": segment involving interaction with physical media, e.g., a whiteboard or paper drawings.
- "Z": segment involving multiple participants.

I appended to this label a three-digit number representing the sequence of the segment in the meeting data, for example, "A001", "B002", "A003", and so on. Figure 3-3 shows an example of several segments with the label attached.

IA researchers often use notation symbols in the transcript to capture detailed aspects of the interaction such as pauses and voice inflections. Most of these symbols are based on the Jefferson System (Jefferson 1984). I chose to use two of these notations:

- *"((italic text))"* to describe non-verbal activity specifically related to use of media, and
- "(text)" to describe speech which is unclear.

I followed the standard practice of separating the segment label by a ":" and starting each segment on a new line. Appendix E is an example of transcript from a meeting and Figure 3-4(b) shows five transcript segments.



i_x	t_{start}	$i_{participant}$	$i_{xtranscript}$
i_1	0	X	((nothing going on - watching 4D model))
i_2	1.27	A	You can see the roofing being installed now.
i_3	1.31	X	*((watching 4D model))*
i_4	1.53	A	Man lift will come up in this area right here and we'll do an interior X model and show balustrades and that sort of thing and we'll show the manlift in the model
i_5	1.73	Z	(question is asked but not heard)
i_6	1.78	A	That's a great question. We'll cover that in that in other model
i_7	1.91	B	What was the question? I didn't hear it.
i_8	1.94	A	Wanted to know if we needed an opening in the roof to get ductwork in?
i_9	2.04	A	To answer his question, the large duct, there is some 54" duct up in the trusses and we'll try to erect those trunklines as they erect the steel
i_{10}	2.28	B	I just stepped it up to every other day now just to get it going faster
i_{11}	2.42	X	*((review of 4D model))*
i_{188}	31.67	B	Yeah, right. Right, here
i_{189}	32.43	A	It's pretty important obviously umm to as the schedule you guys saw us doing the mechanical work and getting all that rough-in done so when we do get the roof poured obviously those are two very critical drains we have to get in because if anybody is working in there they are going to get a bath or a shower if we don't have those drains hooked up. Even if there is no waterproofing membrane on it just water shoot off the roof will reduce it significantly. If there aren't any more questions, why don't we..

Figure 3-3: Overview of the level of analysis in this research. There are several units of analysis. Each observation is a unit of analysis, representing an AEC project meeting, I, to support description and comparison at a meeting level. Each meeting and/or meeting portion is segmented by turns representing a meeting interaction, i_x. Each turn represents a speaking, non-speaking, or overlap segment. The non-speaking segments are either interactions with media or no use of media. This research does not analyze interaction at the utterance or speech act level. The transcription shows the syntax and protocol applied to the video-recorded data. The data is segmented at speaker turns or periods of non-speaking or multiple speakers. Each segment has an identifier, 'A-J' to refer to a specific meeting participant and is numbered incrementally. Double-parentheses and italics highlight non-speaking behaviors.

Table 3-3: Example of raw data exported from the Transana software. The raw data includes (A) a unique identifier for each segment, (B) the duration of the segment in milliseconds, and (C) the transcribed text for the meeting interaction.

Segment (Meeting Interaction) i	(A) Segment Unique Identifier	(B) Duration	(C) Segment Transcript
727	A001-A2	22013	A001: Let's go ahead and start with the hopefully the final sign-off for 4th floor, C. Sure. And uh, Let's go ahead and start with umm. . Let's see. Mainly. Let's go over our last hits. There's only 6 or 7 of them?
728	C002-A3	693	C002: Yeah.
729	A003-A4	1281	A003: All right.
730	X004-A5	6454	X004: *((switching to view))*
731	B005-A6	946	B005: Cable tray is cut.
732	A006-A7	261	A006: Okay.
733	A007-A8	2173	A007: Stop
734	B008-A9	5166	B008: We're supposed to find out if shaft is going to get bigger.

The transcription process is labor intensive, and researchers often cite this as the challenge or barrier to using interaction analysis as a research method (Fairhurst 2004). I used an open-source video transcription software called Transana to manage and organize the transcription and coding process (Figure

3-4) (Woods and Fassnacht 2007). This software greatly facilitated the transcription process by combining features to play back the video, transcribe, and synchronize the transcription with the video, and to create segments, or code those segments. Table 3-3 shows a sample set of the raw data exported from Transana after the initial transcription process and before coding took place. For every minute of video data, this process took approximately ten minutes. An hour of video took approximately ten hours to transcribe and create the segments. This does not include the time I spent programming to automate the generation of the clips from my transcription (see Appendix G for a description of the use and customization of Transana). Other researchers, for example, Futoran et al. (1989) and Milne (2005) who developed an instrument approach to capture and analyze group behavior, report similar amounts of time required to transcribe meeting interaction.

3.3.2 Coding

Coding involves defining coding categories, systematically coding the observations, assessing the reliability of the coding process, and refining the coding scheme(s) (Figure 3-5). As discussed earlier, coding categories relate to the core research concepts and emerge from observation, review of prior research, and during the IA process. It is common practice in interaction analysis to document the coding schemes and categories in a "codebook" (Mayring 2000). This codebook serves two purposes. First, it forces the researcher to define each category and conditions for the categorical distinctions and examples of the category. Second, it serves as a training resource for additional coders requisite for assessing the reliability of the coding scheme and the coding process. Table 3-4 is a sample portion of a codebook. Appendix J, for example, is the codebook used during Phase III (see Chapter 4) and Appendix K is the final codebook representing the proposed mediated interaction analytic scheme.

Table 3-4: Sample of codebook description of a coding scheme titled "Media Type" listing a description for the category keyword, examples, and conditions. This scheme was refined in subsequent research phases.

	Description	Examples
Media Type		
digital	an interaction with a digital representation of an information artifact.	electronic display of information including 2D, 3D, schedule, documents, etc.
paper	an interaction with a paper representation of an information artifact.	2D drawings, schedules, agendas, activity logs
whiteboard	an interaction with an information artifact on a whiteboard or similar physical writing display.	participant uses whiteboard to draw a detail or points to information on a whiteboard
physical	an interaction with a physical model of the 'object' artifact.	scale model of the project, submittal sample
none	an interaction involving none of the media in items 1-4.	these are typically associated with Olson activities such as "digression" or "other"
Accessibility		
shared	media is available to all participants	projected display
semi-shared	media is available to a small group of participants	set of drawings in the middle of a table
private	media is available only to an individual	sketch on a paper placed in front of a meeting participant

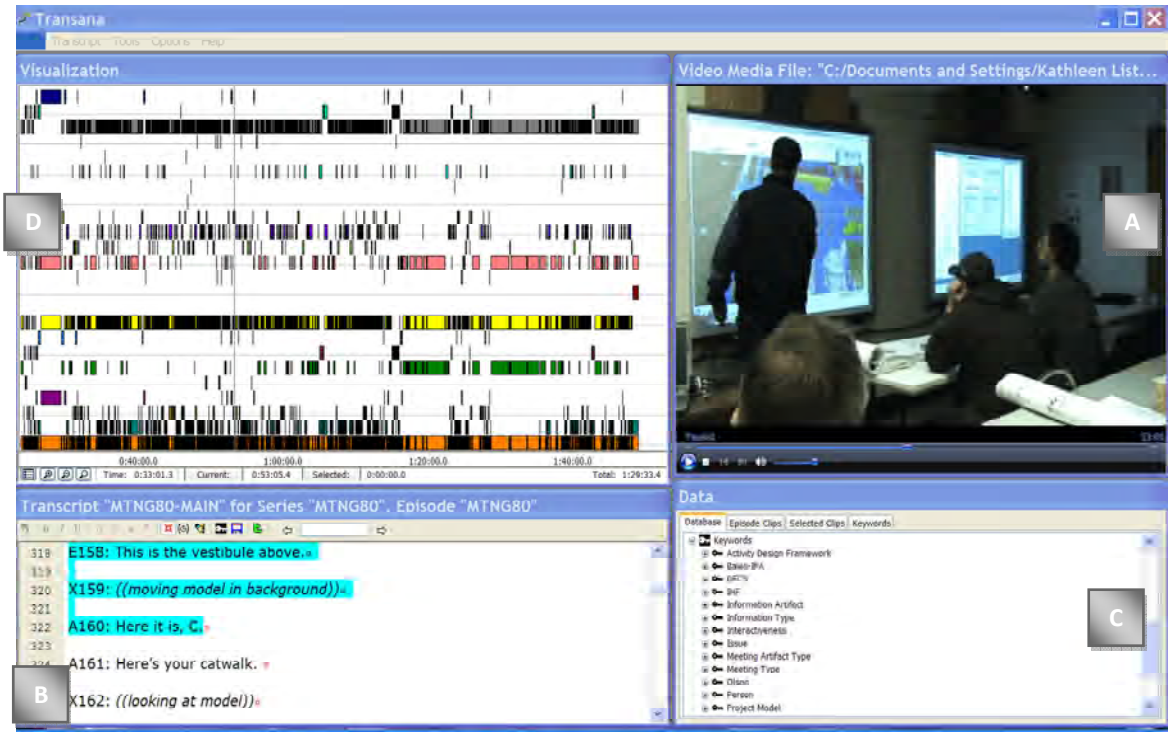


Figure 3-4: Snapshot of the open source transcription software, Transana. The software imports video data (A). Users can create series, e.g., separate observations, and associate multiple video (episodes) and transcripts to those series. Transana provides an interface to transcribe as the video plays (B) and insert time stamps to synchronize the transcription with the video. Users can create collections and store clips in the collections, e.g., collection of clips showing a specific behavior. Users associate clips with user-defined keywords (C), allowing for assignment of keywords to each clips. In the visualization window (D), users can view the current keyword map and assignments over time.

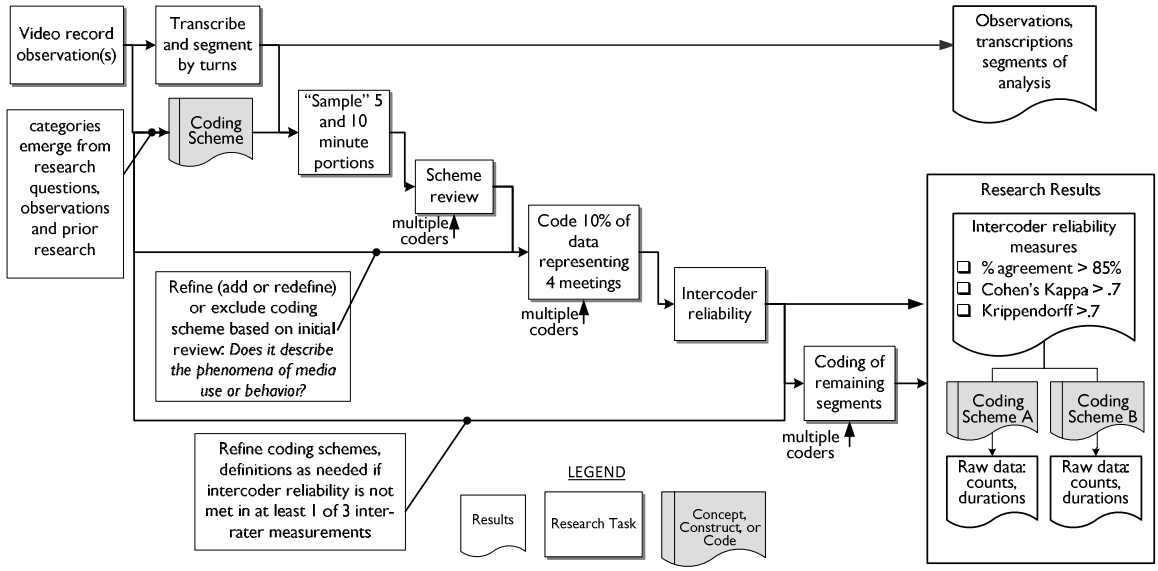


Figure 3-5: Summary of the coding process adapted from (Mayring 2000, p. 4, Figure 1). Mayring describes a process of formative and summative checking of codes. Mayring recommends an iterative process that includes: developing coding categories using criteria established by the researcher, checking reliability and validity of coding categories using 10-50% of data, and doing a final summative check.

Once an initial coding scheme is defined, Mayring (2000) suggests "sampling" the coding scheme by applying the scheme to a portion of the data. I used five and ten minute portions of meeting videos to sample multiple coding schemes during phases II-IV (Figure 3-6). I used the sampling to determine the feasibility of the coding categories and whether the coding scheme yielded insights or discoveries about media use or team behavior. Based on this sampling, I either (a) excluded the scheme from further analysis, (b) redefined coding categories, or (c) added or removed categories. Once a coding scheme passed this initial sampling process, multiple coders (as discussed below) used Transana (Woods and Fassnacht 2007) or Excel to test for intercoder reliability as discussed in the following section (Figure 3-4). I performed this coding process multiple times throughout this research to yield the proposed analytic scheme and the results discussed in Chapters 4 through 6.

Clip ID	Duration (milliseconds)	Text	CDW	RCA	IPA	Media Type	Interactivity	Accessibility	Model Use	DEEP
A001-A2	22013	A001: Let's go ahead and start with the hoop-de-doo, the final sign-off for 4th floor, C. Sure. And uh, Let's go ahead and start with umm. . Let's see . Mainly. Let's go over our last hits. There's only 6 or 7 of them?	meeting management	initiation	gives suggestion	digital	viewing	shared	process	describe
C002-A3	693	C002: Yeah.	meeting management	continue	agrees	conceptual	viewing	NA	process	evaluate
A003-A4	1281	A003: All right.	meeting management	response	agrees	conceptual	none	NA	process	evaluate
X004-A5	6454	X004: *((switching to view))*	walkthrough	communication	na	digital	changing	shared	product	describe
B005-A6	946	B005: Cable tray is cut.	clarification	initiation	gives orientation	digital	viewing	shared	product	describe
A006-A7	261	A006: Okay.	clarification	response	agrees	digital	viewing	shared	product	describe
A007-A8	2173	A007: Stop	meeting management	order	gives suggestion	digital	changing	shared	process	describe
B008-A9	5166	B008: We're supposed to find out if shaft is going to get bigger.	issue	initiation	gives suggestion	digital	viewing	shared	product	evaluate
A009-A10	3454	A009: Yep. I Still don't have answer on that.	clarification	response	agrees	conceptual	none	NA	product	evaluate
B010-A11	8335	B010: That's going to be broken in 2	issue	communication	gives orientation	digital	viewing	shared	product	predict
A011-A12	3857	A011: Did you note that anywhere on yours, D?	clarification	initiation	asks for orientation	digital	viewing	shared	product	describe
D012-A13	197	D012: I didn't.	clarification	continue	gives orientation	digital	viewing	shared	product	describe
A013-A14	1885	A013: Okay.	other	response	agrees	none	none	NA	NA	NA
D014-A15	4134	D014: There's a lot of those that are going to be broken. and I can't draw it.	criteria	communication	gives orientation	digital	viewing	shared	product	explain
D016-A17	4471	A015: You can't....	criteria	initiation	gives opinion	none	none	NA	product	explain

Figure 3-6: Sample of the raw coded data in Excel. Each segment in the raw data, e.g., the segment with "Clip ID", "A001-A2", includes duration in milliseconds, text, and keyword assignments for various coding schemes (See Chapter 4).

The coding process was less time intensive than the transcription process. Sanderson et al. (1994) reported analysis time to sequence time (AT:ST) ratios ranging from 3:1 to 10:1, or higher. Nyerges (1998) reported (AT:ST) as 2.4:1. Our AT:ST ranged from 3:1 to 5:1 depending upon the number of coding schemes that were applied to the data. In Phase IV, using the final analytic scheme, the AT:ST was between 2.5:1 and 3:1. Thus, a significant amount of the effort was in the development and refinement of the coding scheme as opposed to the actual process of coding.

3.3.3 Intercoder Reliability

Qualitative research and methods such as interaction analysis involve interpretation of the real world. In qualitative research, *reliability* refers to whether the data collection and analysis procedures are repeatable and replicable. Measures vary in time, over and within observations, and as a function of researcher interpretation and contextual factors (Kirk and Miller 1986; Seale 1999). While there is much debate as to the role of reliability in qualitative research, the consensus is that researchers are responsible

for reporting reliability methods and the factors that affect repeatability and replicability in their research findings (Kirk and Miller 1986; Seale 1999; Lincoln and Guba 1984). To the extent possible, I heeded this advice.

In interaction analysis research, intercoder reliability is the most common method to assess and report reliability. Intercoder reliability (also referred to as interrater, interobserver, interannotator, or concordance) is "the extent to which the different judges tend to assign exactly the same rating to each object" (Tinsley and Weiss 1975, p. 98). The purpose of reliability measures is twofold in interaction analysis: (1) to accompany a detailed description of the coding process with reliability measures, and (2) to acknowledge the level of disagreement and the sources of that disagreement. Intercoder reliability acts as an invaluable guide for IA researchers. When reliability measures fall short of accepted standards it encourages the researcher to refine the coding categories.

No analytic scheme is 100% reliable; reliability is a function of scheme definition, coder training, methods of observation and data collection, and coder objectivity. It is common for researchers to find reliability problems with analytic schemes developed by prior researchers and to produce different reliability measures with the same analytic scheme. Multiple researchers, for example, have refined or adapted Bales' IPA analytic scheme (Bales 1950) to improve reliability (Psathas 1961; Waxler and Mishler 1966) and found that different observational methods, via tape or observation, yielded different results. Reliability measures alone are not a criterion to assess the quality of the research. The previous sections detailed the observation and coding process; here I elaborate the iterative process of using reliability measures to assess the coding schemes.

I performed various methods of intercoder reliability throughout the research and used the results to refine and improve the analytic scheme. I followed the guidelines for intercoder reliability documented in (Tinsley and Weiss 1975) and (Lombard et al. 2002):

1. select intercoder measure(s) and criteria for acceptance,
2. perform intercoder reliability during each research phase and analytic scheme modification,
3. assess reliability formally in last phase of research with appropriate sample size,
4. address disagreements, and
5. report reliability process.

The following paragraphs discuss these steps, and in doing so I meet the criterion of Step 5.

Reliability Measure and Acceptance Criteria. In the literature there is no standard criterion for calculating intercoder reliability, and there is much debate as to the appropriate measure and criteria for acceptable reliability (Carletta 1996; Eugenio and Glass 2004; Craggs and Wood 2005; Hayes and Krippendorff 2007). Research in interaction analysis, content analysis, and discourse analysis includes studies with detailed reporting of multiple measures to studies reporting no measures (DeSanctis and Poole 1994; Milne 2005). The most commonly cited measures in the studies closely related to this research are percent agreement, Cohen's Kappa, and Krippendorf's Alpha. Table 3-5 summarizes these measures, the

methods to calculate these measures, and the acceptable criteria. Appendix I discusses these methods in detail and explains the rationale for choosing these three methods.

Table 3-5: Summary of intercoder reliability measures used in this research. Three measures of agreement were applied in Phase IV, including Percent Agreement, Cohen's Kappa, and Krippendorf's Alpha. The method used to calculate the reliability measures are listed and the measures for high intercoder agreement and acceptable intercoder agreement.

Intercoder Reliability Measure	Method	High Intercoder Agreement	Acceptable Intercoder agreement
Percent Agreement	$P_a = \frac{O_a}{U_t} = \frac{Observer\ agreement}{Total\ Units\ of\ Analysis}$	➢ .8	➢ .7
Cohen's Kappa (κ)	$\kappa = \frac{P_a - P_e}{1 - P_e}$, P_e = Agreement by Chance	➢ .8	➢ .4
Krippendorff's Alpha (α)	$\alpha = 1 - \frac{D_o}{D_e} = \frac{\text{Observer Disagreement}}{\text{Expected Disagreement}}$	➢ .8 to make scholarly arguments	➢ .667 to make tentative conclusions

Reliability Process in Phase II. In Phase II, I used percent agreement as the sole measure to identify problems with coding categories. I used coders from a group of students in a research seminar that I taught with a colleague at Stanford. Five coders applied the DEEP coding scheme (see Appendix K.6) to a twenty-minute portion of a video-recorded meeting. P_a measures ranged from 5% to 98%. I further analyzed the data to identify which categories were associated with higher levels of disagreement. For example, the most common disagreement was between the categories of "explain" and "describe." Based on this type of analysis, I refined the definitions of the categories, added a category, and refined the training process.

Reliability Process in Phase III. In Phase III, four coders, including myself, coded portions of the meetings. During a two-year period, I tested fifteen coding schemes and variations of those schemes. I used the reliability measures to identify reliable coding scheme and to eliminate unreliable coding schemes. In the latter part of Phase III, I selected nine meetings to analyze totaling 523 minutes and 4,800 segments. Tinsley et al. (1975) recommend a sample size no less than 50 units or 10% of sample size to perform reliability. I selected four meetings from the nine meeting set, representing the range of media use and interaction, and each coder coded a twenty-minute portion of the segment using eight analytic schemes. This sample set represented more than 10% of the recommended sample size in units and time.

Reliability Process in Phase IV. In Phase IV, two coders, including myself, coded the remaining portion of the nine meetings using the final analytic scheme. One coder coded all meeting interactions and the additional coder coded 15% of meeting interactions. I made several refinements to one of the analytic schemes to meet the intercoder reliability criteria listed in Table 3-5.

Disagreement Resolution. Many studies report processes of addressing disagreement in the coding process. Some researchers use a consensus process and review units with disagreement and mutually agree on the final coding category. Other researchers identify an iterative process of multiple coders working together to code the data and to work towards a consistent interpretation of the data. At each phase, I used an Excel worksheet to compare coding values between the coders. I would review the worksheet and add comments to the coders' coding worksheets, and we would meet weekly to discuss the coding schemes and

problems with the coding schemes. In the final phase after intercoder reliability measures reached acceptable levels, the coders continued to work together and resolve issues of disagreement.

3.4 Analysis of Observations: Describing and Comparing Patterns of Mediated interaction

Analysis is the critical step of synthesizing the data and operationalizing the constructs to describe and compare mediated interaction. The analysis process, as shown in Figure 3-7, unfolded over many iterative steps starting with basic analysis of the categorical data to describe meeting interaction, gradually moving towards the development of process measures by operationalizing constructs, and resulting in the development of new analytic methods. The tasks utilized a variety of methods drawn from social science research, research using interaction analysis, and research investigating group interaction.

Qualitative research seeks illumination and understanding (Golafshani 2003), whereas quantitative research seeks causal explanations and uses numbers and statistics to present findings (Strauss and Corbin 1998). Interaction analysis is a qualitative approach that uses quantitative data. The transcription and coding process produces raw coded data that is categorical, qualitative, quantitative, and temporal. Researchers use these data to quantitatively describe and compare interaction processes. A small subset of IA researchers use statistical methods to identify trends in the data by comparing categorical data or comparing the IA data to independent or dependent input or output variables. I used both approaches in the development of this approach to:

(a) Describe meeting interactions using rates and proportions (Section 3.4.1).
(b) Describe and compare meeting interactions using measures and metrics (Section 3.4.2).
(c) Describe meeting interaction patterns using keyword maps and sequential analysis (Section 3.4.3).

The following sections summarize these methods and how each of these methods contributed to the development of the mediated interaction approach. This discussion focuses on the method I use that other researchers also employ. In Chapters 5 and 6, I discuss the methods I developed to improve upon these methods when the current methods failed to communicate the dynamics of media use and team interaction, and the patterns of mediated interaction.

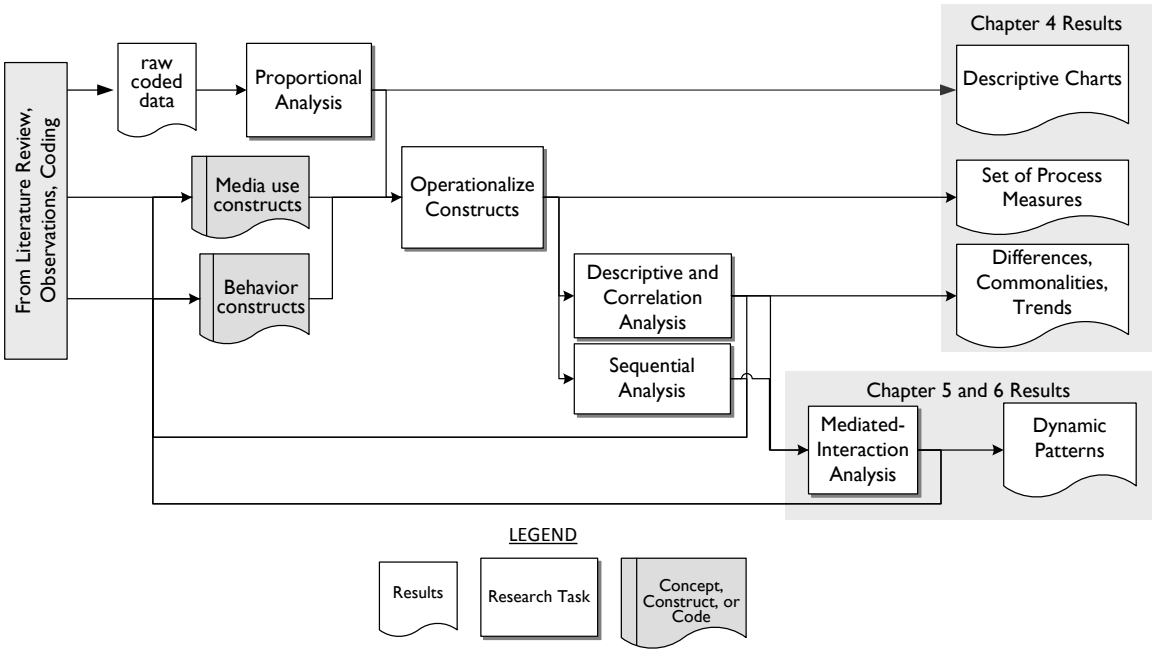


Figure 3-7: Summary of the analysis research tasks to use the raw coded data to describe and compare mediated interaction. The methods discussed in this chapter relate to the findings in Chapter 4 and are the basis for the methods developed in Chapters 5 and 6.

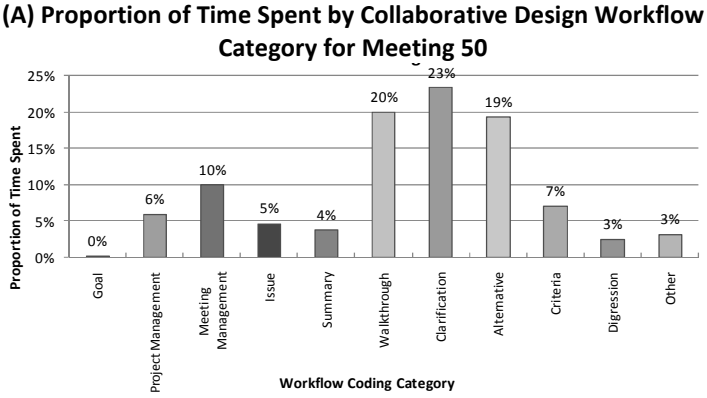
3.4.1 Categorical Rates and Proportions: Describing Meeting Interaction

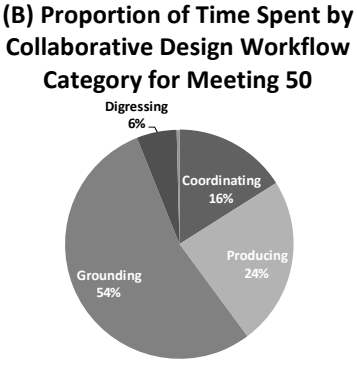
One of the primary uses of IA data is for descriptive purposes. Bakeman and Gottman (1986) refer to two types of basic descriptive analysis: rates and proportions. Rates refer to how often a specific coded event or activity occurred over a time period. For example, a rate of observing the behavior "agrees" would be equal to the number of times a coder assigns "agrees" to a segment divided by the total time for the observation such as that shown in the column "Agreement Rate" in Table 3-6. Rates support comparison across observations. The second type of descriptive analysis is proportions or the relative amount of time the team spent doing "something" or the total time a coder observed a phenomenon. The columns, titled "Agreement Portion", in Table 3-6 lists proportions by count and by time. These methods produce different results. For example, Meeting 60 has the highest "Agreement Rate", but as a proportion of time, the team in Meeting 90 spent more time "Agreeing". I used all of these methods to identify appropriate and relevant descriptors and comparative methods.

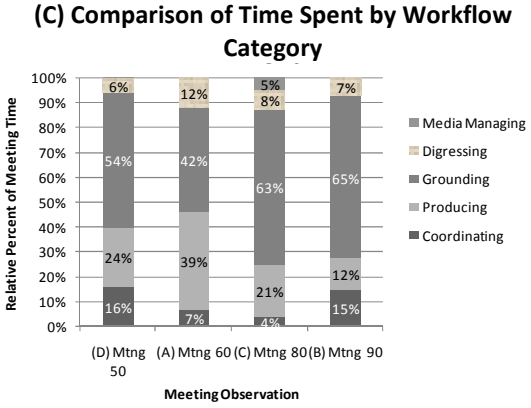
Proportional analysis of all categories in a coding scheme describes the relative time spent per category. Figure 3-8(a), for example, shows a bar chart and pie chart showing proportional analysis of a "workflow" coding scheme developed by Olson et al. (1992) applied to a single meeting observation. Figure 3-8(b) shows an aggregated proportional analysis using higher-level categories in a pie chart. Figure 3-8(c) compares the higher-level categorical analysis of four meetings using a stacked bar chart.

Table 3-6: Example of comparing categorical rates and categorical proportions by count and time. The example uses the behavior "agrees" to illustrate how the three methods produce different results. In this case, segments associated with "agree" are typically shorter segment durations than other interaction segments and represent a smaller proportion of the time spent but represent a higher proportion of the interaction segments. The rate of agreement (agreement interactions per minute) tells how often the team agrees and does not equate with proportional measures. The researcher must provide the rationale for using counts, proportions, or rates for various types of behavioral analysis.

Observation	Meeting segments [#]	Meeting Duration [minutes]	Counts [#]	Duration for Category [minutes]	Agreement Rate [#/minutes]	Agreement Proportion [#/#]	Proportion of Time Spent "Agreeing"
	I_N	I_D	b_{agrees}	$\sum_{x=0}^{x=N} b_{agrees*}\, i_{x,d}$	$\frac{b_{agrees,c}}{I_d}$	$\frac{b_{agrees,c}}{I_n}$	$\frac{b_{agrees,d}}{I_d}$
Meeting 50	1066	96.0	87	2.7	.91	.08	.03
Meeting 60	155	29.7	16	.3	.54	.10	.01
Meeting 80	859	106.6	39	2.9	.37	.05	.03
Meeting 90	726	62.3	67	1.6	1.08	.09	.03





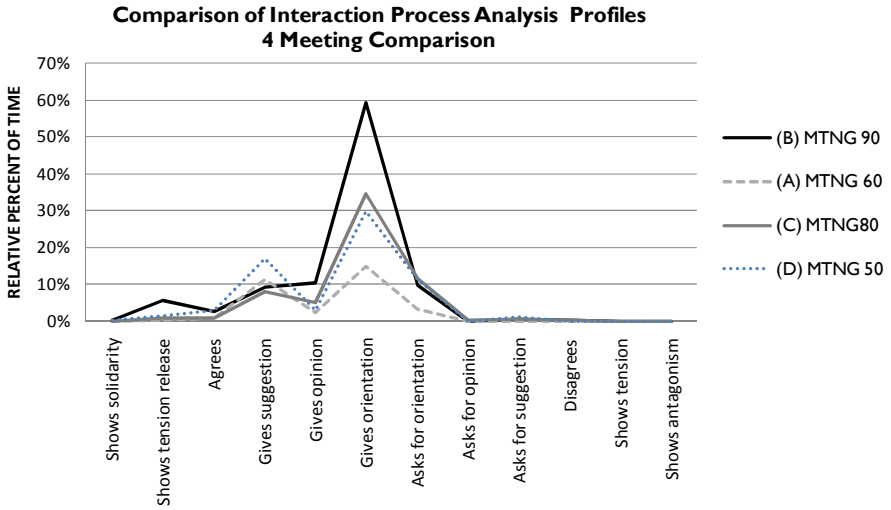


(D) Proportional Analysis of Time Spent by Workflow Category

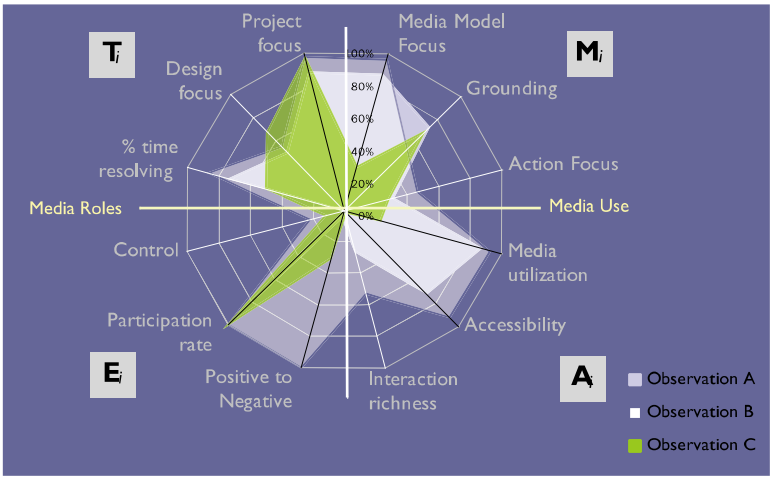
	Mtng 50 (D)	Mtng 60 (A)	Mtng 80 (C)	Mtng 90 (B)
Coordinating	16%	7%	4%	15%
Producing	24%	39%	21%	12%
Grounding	54%	42%	63%	65%
Digressing	6%	12%	8%	7%
Media Managing	0%	0%	5%	0%
Average ($\tilde{x}$)	20%	20%	20%	20%
Standard Deviation (σ)	21%	19%	25%	26%
Minimum	0%	0%	4%	0%
Maximum	54%	42%	63%	65%

Figure 3-8: Comparison of three different charting methods displaying results from a proportional analysis using a Collaborative Design Workflow (CDW) coding scheme developed by Olson et al. (1992) (see Appendix K.1). (A) The bar chart compares time spent for each workflow category. (B) The pie chart compares time spent for high-level categories, grouping the detailed categories to show how the team spends time grounding, coordinating, producing, digressing, and managing media. See Chapter 4 for a discussion of these workflow categories. Pie charts, (B), are useful to describe a single meeting, but (C) bar charts are more useful for comparison across meetings. (D) Lists the raw proportional data showing the average, standard deviation, and range of values. For example, this comparison shows differences in time spent grounding, ranging from 42% to 65%.

These descriptive approaches, though, do not provide a structured or consistent way to compare meeting interaction or identify categorical patterns from different meetings. One approach is to order categories systematically using interaction profiles or radar charts. Bales (1950), for example, created a standard chart, an Interaction Process Analysis diagram, to compare multiple group interactions and describe patterns of interaction (Figure 3-9). These diagrams support visual and quantitative comparison in a systematic way. The layout and order of the categories reflect relationships between categories.



(A) Interaction Analysis Profile



(B) TEAM profile

Figure 3-9: Two comparative profile diagrams. (A) The Interaction Process Analysis profile developed by Bales (1976) compares the socio-emotional and task activity of groups. All meetings in this example exhibit the same general profile pattern with a majority of the time spent "giving orientation". (B) A "TEAM" profile produced in Phase II and early Phase III of the research to compare multiple categorical measures of behavior and media use (Liston 2007). The differences in the sections show variations in how the teams behaved and used media. Profiles order categories consistently to describe and compare aspects of interaction.

3.4.2 Measures, Metrics, and Indicators: Comparing Within and Across Observations

The descriptive methods in the previous section provide no means for interpreting the differences in proportional data or the profiles. Raw proportional analyses, profiles, and bar or pie charts offer a relative comparison that require the researcher and the reader to interpret the meaning of those differences. These charts operationalize constructs as a process measure relative to overall meeting time. A *measure* is "the extent, dimensions, or amount of observed process phenomena, especially as determined by a standard" (IEEE Standard Glossary as cited in Ragland 1995, p.1). The proportional measures listed in Table 3-5 are examples of process measures. These process measures, though, provide no indicators or means to interpret those measures. A metric associates a measure or set of measures with a relative standard or along a scale to gauge and interpret the measure(s) and allows for comparison and interpretation.

> **metric (n):** "*a quantitative measure of the degree to which a system, component, or process possesses a given attribute. A calculated or composite indicator based upon two or more measures. A quantified measure of the degree to which a system, component, or process possesses a given attribute"* (IEEE Standard Glossary as cited in Ragland 1995, p.1).

Businesses develop metrics by which to assess their performance. Businesses compare measures and metrics to baselines or *indicators*. There are two types of metrics: normative and descriptive metrics. Normative metrics establish a normative or ideal value, and the measure reflects the extent to which that behavior achieves that value. For example, Bales (1976) developed indicators of typical interaction by analyzing hundreds of small groups in the lab using Interaction Process Analysis (See Appendix K.3). Bales then used these indicators as a basis for comparison in subsequent studies. Researchers also create metrics that distinguish behavior along a scale. An example of this are satisfaction measures that use Likert scales ranging from unsatisfied to satisfied. One can readily interpret the satisfaction results using this indicator scale and distinguish between less ideal (less satisfied) satisfaction values and more ideal (satisfied) satisfaction values.

Another example of a metric is the Gini coefficient that measures the equality of participation. The Gini coefficient (Alker 1965; Dixon et al. 1987; Weisband et al. 1995) measures the inequality of participation as the deviation of each participant from equal participation where a value of 0 represents equality among participants and a value of 1 represents dominance by a single participant. The Gini coefficient sums, over all the group members, the deviations of each from equal participation, normalized by the maximum possible value of this deviation (Weisband et al. 1995). Table 3-7 lists the Gini coefficients for nine meetings analyzed in this research. The metric provides a comparative scale, but, in the absence of relation to other measures, it does not tell us whether dominance or quality is a factor in the process or the outcome.

Table 3-7: Comparison of Gini coefficients for nine project meetings. The Gini coefficient metric is a scale from 0 to 1 with a 0 value representing equal participation by all meeting participants and a value of 1 representing dominance by one project participant.

Meeting	Gini Coefficient
(E) Mtng 1	0.74
(F) Mtng 10	0.60
(G) Mtng 20	0.62
(H) Mtng 30	0.62
(D) Mtng 50	0.64
(A) Mtng 60	0.53
(I) Mtng 70	0.52
(C) Mtng 80	0.50
(B) Mtng 90	0.41
$\bar{x}$	.58
σ	.09

There are three challenges with respect to the use of process measures and metrics to describe and compare meeting dynamics. First, no standard set of meeting process measures or metrics exists. Consequently, researchers develop their own study-specific process measures and methods to calculate the measures (see discussion in Chapter 2). Researchers who operationalize the same process construct often use different data collection methods and different operational definitions. I, too, developed my own process measures. Second, researchers typically use process measures as the basis of their findings or results. In this research, I first operationalize constructs using process measures and then operationalize them as a metric that represent the range of media use and interaction. I use process measures to identify typical and atypical behavior and to identify how interactions are similar or dissimilar. I use descriptive analysis, including mean, average, and standard deviation, to identify variability across process measures and identify commonalities and differences in meeting interaction. Finally, the process measures researchers use typically measure the process as a whole and do not measure differences that occur moment-to-moment. Consequently, I had to develop a method and metric that supports measurement at the level of interaction.

I used correlation analysis to identify relationships across categories, validate relationships across categories, and determine to what extent process measures (variables) vary together. Ultimately, the correlation analysis did not yield significant findings but it did play an instrumental role in my analytic process. Correlation analysis often identifies relationships between variables when independent or dependent variables are not included in the study. Coefficients range from -1, negative correlation, or variables trend opposite to one another to 1, positive correlation, or variables vary together. Olson et al. (1992), for example, used descriptive analysis combined with inter-correlation analysis to show how the overall distribution of time spent in meetings was similar across the ten software design meetings analyzed in their study. I used correlation analysis to compare coding schemes, particularly in the development of categories to represent constructs. For example, several categories I applied to the observations in separate coding schemes are similar, such as “ask” and “clarification”. In this manner, I validated the constructs and coding categories with correlation analysis to ensure that dissimilar and similar categories were negatively and positively correlated.

3.4.3 Keyword Maps and Sequential Analysis

Proportional analysis and calculation of process measures are the most common methods reported in the literature. These methods abstract and reduce the process and coded data into a set of static measures and charts. There are two less common methods researchers use to analyze and communicate the process dynamics: (a) sequential analysis, and (b) visual analysis of patterns using timelines or sequence maps.

Lag Sequential Analysis

A method to identify sequence relationships is lag sequential analysis (Sackett 1979; Bakeman and Gottman 1986; Gottman and Roy 1990). Lag sequential analysis examines the sequence of patterns and probability of events occurring in sequence. The method uses frequency rates and transition probabilities between "states". Researchers use these data to create transition state diagrams. Figure 3-10 compares two transition state diagrams for a communication coding scheme applied to two meeting observations. The purpose of the diagram is to show patterns of interaction. Jeong (2006), for example, compared patterns of online communication using these diagrams. Putnam (1983) used lag sequential analysis to compare high procedural and low procedural groups and identified patterns distinguishing these groups. Putnam's research used one categorical scheme and involved manual and highly detailed quantitative comparison. De Laat et al. (2007) generated similar transition diagrams to compare interaction patterns in social network learning. For the researcher, these diagrams offer insights, but require significant time to interpret and extract patterns. They capture some notion of temporality or sequence from a single categorical perspective. I experimented with these diagrams, but did not apply them to all observations.

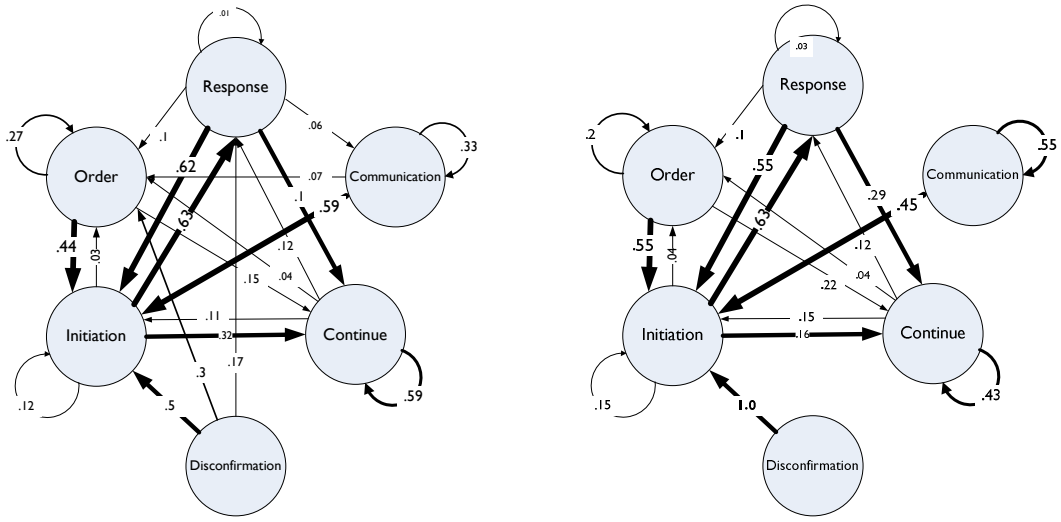
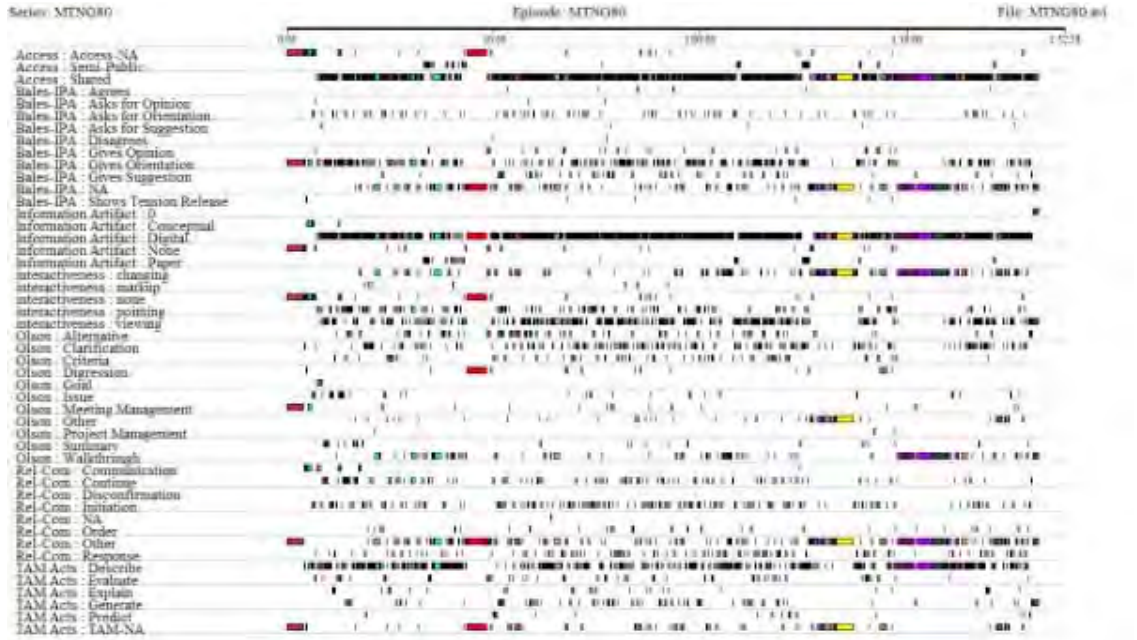


Figure 3-10: Example of a transition state diagram generated using lag sequential analysis and probabilities of state transitions. The examples use raw Relational Communication analysis coded data (see Chapter 4 and Appendices J4. and K.2) to compare the relational communication process for two meetings. The diagrams show similar relational patterns, dominated by the sequence of initiation-response and initiation-continue-response interactions.

Sequence Maps and Timelines

Less common are the use of visual timeline techniques to communicate categorical relationships and meeting dynamics using interaction analysis. These methods include activity graphs (Benshon 1967), keyword maps (Nathan et al. 2007) (see Figure 3-11), activity charts (Gero and McNeill 1998), and chronologically ordered representations (Luckin 2003). These methods are similar to Gantt charts or activity timelines that map coded activity over time. Gero and McNeill (1998), for example, layer macro and micro-level analysis using multiple activity charts. Luckin (2003) uses an activity chart to show interactions between children and between children and media. Hmelo-Silver (2004) uses a similar approach to investigate the dynamic between students, conversations, and online collaborative environments. Stumpf (2001) uses timelines to show changes in a designers' use of persuasive schemes. In all cases, though, the use of these timelines was limited to short periods of analysis.

(A) Keyword Map for Multiple Coding Schemes



(B) Keyword Map for a Single Coding Scheme

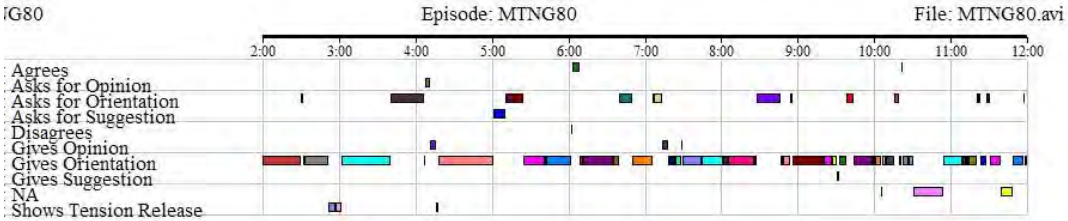


Figure 3-11: Three keyword maps for a meeting observation showing the various keyword assignments by coding category. (A) The top keyword map shows multiple categories and keyword assignments. It is difficult to read but shows the large amount of data produced and challenges with using keyword maps to describe patterns of interaction from multiple perspectives using multiple keywords. The large number of categories and large set of interactions makes it difficult to discern relationships across multiple categories of analyses. (B) The bottom keyword map shows only keywords for a single categorical coding scheme.

I used keyword maps throughout the coding and analysis process to visually validate and analyze the meeting interaction. First, I used them to identify gaps in the coding categories by identifying holes or spaces in the keyword maps without any keyword assignments. Second, I used the maps to identify relationships across categories by identifying patterns of keyword bars and then compared that to the descriptive and correlation analysis. There are several challenges with the keyword maps. For large sets of data, it is hard to discern or readily see relationships. I generated the keyword maps using Transana (Figure 3-11 [a] and [b]) and Python scripts that I developed. One of the challenges in this research is that the display of categorical, temporal data is difficult in statistical or standard spreadsheet applications. In Chapters 5 and 6, I discuss the methods I used to improve upon these standard keyword maps and to communicate the dynamic relationship between categories.

Tables 3-8 and 3-9 summarize the visual methods employed by studies examining patterns of team interaction or team interaction and media use. The list is not an exhaustive list of visual methods. These studies inspired my approach in small ways and in their use of novel visual methods. Generally, though, few studies move beyond the typical use of narratives, process measures, and correlation tables. Most studies completely ignore the temporal aspect of interaction or media use. The studies in Tables 3-8 and 3-9 represent the few studies that attempt to examine how a construct changes over time and use methods that convey these dynamics.

Table 3-8: Summary of studies employing visual methods to describe patterns of team interaction.

Study	Description	Constructs Examined	Level of Analysis	Pattern Types	Method to Communicate Pattern
(Bales 1970)	describe social and task processes of small groups	socio-emotional and instrumental task	conversation	socio-task patterns	interaction profiles
(D'Astous et al. 2004)	break interaction into sequences, exchanges, and moves associated with new subjects (themes, topics related to artifact) and patterns of activity	workflow: sequences and moves	meetings	yes. patterns of transitions or workflow.	textual, narrative, and proportional charts
(Foley and Macmillan 2005)	examined the participation of meeting participants by role and transition between participants	participation, dominance	meeting	patterns of "role" transitions	interaction flow analysis
(Rogers and Farace 1975)	examine communication and control aspect of communication	control	conversation	patterns of relational communication	lag sequential data table
(Kan and Gero 2005)	examines relationship between design moves and topics	design productivity	minutes	design moves	linkography diagram (Goldschmidt 1991)
(Minneman 1992)	making sense over time	making sense	interaction		activity design framework

Table 3-9: Summary of studies employing visual methods to describe patterns of team interaction and media use concepts/constructs.

Study	Description	Constructs Examined	Level of Analysis	Pattern Types	Method to Communicate Pattern
(Olson et al. 1992)	examines effects of media use on workflow	workflow	meeting	patterns of collaborative workflow	transition diagram
(Maldonado et al. 2007)	process of adopting media	productivity	project (months)	patterns of idea generation	sparklines
(Losado et al. 1990)	socio-emotional and task interactions using and not using media	none	task	yes	transition diagrams
(Bélanger and Watson-Manheim 2006)	transitions from one mode of media to another media.	transitions	everyday activity	no	textual
(DeSanctis and Poole 1994)	examines mutual process of media use and structuring	structuration	meeting, months	no	coding analysis diagram
(Maznevski and Chudoba 2000)	examined patterns of interaction, developed a construct "interaction intensity" to capture team dynamics	flow, rhythm of communication/ interaction	months	patterns of interaction intensity and relate to effective/ ineffective groups	abstract charts showing interaction intensity/time
(Orlikowski and Yates 1994)	examined different uses of media for different purposes to define "repertoires"	use	months		charts showing usage by media type/time.
(de Laat et al. 2007)	patterns of interaction using social networking analysis	connectedness	workshop, learning task	patterns of connectedness	interaction pattern (transition diagram)

3.5 Validating the Approach and Assessing the Quality of the Research

Methods to validate quantitative research are generally accepted and well documented, whereas methods to validate qualitative research are more ambiguous and riddled with debates, arguments, and recommendations (Kirk and Miller 1986; Maxwell 2002). Some argue the issue is not validity of the research but the quality of the research and that rigorous methods found in quantitative research are not applicable to qualitative research. Lincoln and Guba (1985) suggest a set of criteria to judge validity, shown in Table 3-10, that relate to the conventional validation methods common in quantitative research. I address each of these criteria in the following sections and conclude with a discussion of construct validity.

Table 3-10: Comparison of criteria for judging the quality of quantitative versus qualitative research based on (Lincoln and Guba 1985, p. 300; Hoepfl 1997).

Conventional terms	Naturalistic terms
internal validity	credibility
external validity	transferability
objectivity	confirmability
reliability	dependability
construct validity	

Internal validity refers to the extent to which the findings reflect reality (Hoepfl 1997), the richness of the information gathered, and the analytical abilities of the researcher (Patton 1990). Maxwell (2002) refers to descriptive validity, a similar concept, as the degree to which researchers accurately report what they see and what they omit from their results. In this chapter, I discussed in detail my various observation and data

collection methods and defined the scope of those observations. Where pertinent in subsequent sections, I discuss what I omit from the results.

External validity refers to the generality of the research to other researchers, domains, or meeting processes. The claims in the research pertain to the generalization of the proposed method to multi-disciplinary AEC face-to-face project meetings using a variety of digital and physical media. Table 3-1 and 3-2 describe the range of meetings observed from conceptual design to construction schedule review and range of media observed. The meetings did not include web-based media or videoconferencing media. I observed meetings ranging from concept design to construction.

Objectivity is the extent to which the researcher can demonstrate the neutrality of the research interpretations, either through a "confirmability audit" (Lincoln and Guba 1985) or by providing an "audit trail" (Hoepfl 1997). I included in this chapter some of the early work and references to early research that describe preliminary findings. The appendices include raw data from the transcripts, coded data, and proportional analysis of the meetings. In subsequent chapters, I discuss the evolution of the constructs using examples from the observations.

Reliability. Section 3.3.3 discussed the reliability methods related to the observation/video coding and survey data.

Construct validity refers to the extent to which the operational measure I select, that is, analytic schemes and methods, "actually measures what it purports to measure" (Iavari 2005, p. 15). There are two types of construct validity referenced in the literature: discriminant and convergent. Discriminant refers to the degree to which measures should not measure the same thing, and convergent, the degree to which measures should measure the same thing. I address both of these by building on prior research concepts, constructs, and commonly accepted measures. I use the satisfaction data as a comparative measure for convergent validity for the team interaction construct since it is the closest construct for assessing socio-emotional, process, and outcome aspects of the meeting process. All of the schemes used in the research build on prior conceptualizations and constructs (see Chapter 2). I used correlation analysis to validate that similar measures were similar and dissimilar measures were dissimilar.

With respect to construct validity of the visualization methods I developed, I compare these methods to prior methods where applicable. I compare the findings from using the proposed methods to the findings from prior methods to show that the methods improve upon existing methods.

To summarize, I addressed construct validity by:

(a) enfolding constructs from the literature to address the theoretical validity of the research constructs;
(b) using multiple measures for each construct to address divergent and convergent validity;
(c) performing correlation analysis to compare different measures reflecting various constructs; and
(d) comparing proposed methods to previous methods.

Chapter 4: Mediated Interaction Analysis

"Developing a coding scheme is very much a theoretical act, one that should begin in the privacy of one's own study, and the coding scheme itself represents an hypothesis, even if it is rarely treated as such. After all, it embodies the behaviors and distinctions that the investigator thinks important for exploring the problem at hand. It is, very simply, the lens with which he or she has chosen to view the world." (Bakeman and Gottman 1986, p. 15)

In Chapter 2, I constructed the theoretical lens for investigating the relationship between team interaction and media use and proposed a conceptual research model, the Mediated Interaction Model (Figure 2-7), that integrates and builds on prior conceptualizations of team interaction and media use. MIM conceptualizes team interaction as multi-purpose and analyzable at three levels of analysis: project, meeting process, and interpersonal interactions. The goal is to operationalize the MIM concepts using observations of meeting interaction and to analyze, at a micro-level, the role of media use in team interaction. Operationalizing and applying this model and its concepts to project meetings requires the development of a coding scheme to label and interpret behaviors associated with MIM processes (Bakeman and Gottman 1986). This chapter discusses the development of the coding scheme that enacts MIM and answers the following research question:

(RQ2) How can the meeting interaction process be interpreted and analyzed to describe differences in how teams use media and how teams interact in video-recorded meeting interaction?

The chapter answers this question by discussing the development, refinement, and application of the *Mediated Interaction Analytic* (MIA) scheme and applying this scheme to nine meetings to describe differences in team interaction, from multiple perspectives and at multiple levels of analysis, and media use. I compare prior coding schemes in two parts: 1) using comparative matrices representing MIM and 2) applying prior coding schemes to meeting observations. This comparative analysis extends the literature review and highlights the gaps in prior coding schemes and challenges in operationalizing some of the MIM concepts.

The MIA scheme addresses three key gaps in prior coding schemes. First, no single scheme or set of schemes captures the communication, reaction, and action aspects of interaction at the three levels of analysis. Second, MIA interprets non-verbal periods of interaction from these three perspectives. Third, MIA captures the process of using multiple media in a meeting media context and "transitioning" and "accessing" in moment-to-moment interaction. In some cases, I show the need to elaborate two processes, "grounding" and "relating", to make meaningful distinctions and the rationale to exclude two concepts from analysis, "controlling" and "participating". I do not re-conceptualize MIM and include this discussion to define the rationale for the scheme and what aspects of team interaction and media use I examine in this dissertation.

I apply MIA to nine meetings using existing observation-based methods to describe differences in how teams interact and how teams use media. These results show that typical meeting interaction is "exchanging", "describing", and "communicating" and atypical meeting interaction is "expressing" and "structuring". The findings show a wide range of media use; typical media use is "utilizing", "viewing", and "communicating". The results provide evidence for MIA's generality and power to describe differences in all aspects of team interaction and media use. The results, though, primarily serve to illustrate the shortcomings of existing visualization methods to use coded observation data to describe and compare multiple perspectives of the interaction process. Consequently, the results presented here are disparate and do not yield significant insights into the relationship between team interaction and media use.

4.1 Criteria for an Analytic Scheme

The design of an analytic scheme must take into account a multitude of issues, such as purpose, reliability, and usability. Casting a "wide net" to capture every nuance in a meeting may lead to undesirable results and unmanageable data. Making too few distinctions or poorly defining those distinctions may also lead to undesirable and unreliable results. In summary, I designed the analytic scheme to meet the following criteria:

(a) The coding categories should represent the analytic processes in MIM (Figure 2-7) and label interpersonal behaviors associated with a single MIM process.

(b) Every discrete meeting interaction should be interpretable from the team interaction perspective and media use perspective and at one level of analysis (project, process, and interaction) (See Chapter 2, Section 2.2.3 for a description of these levels of analyses). The resulting coding data is a set of behaviors comprising at least one behavior associated with communication (C), action (A), or reaction (R) and one media use behavior (M) (Formula 4-1).

(c) The coding scheme(s) should be usable such that a trained coder can readily interpret and apply the scheme to meeting interaction.

(d) Each coding scheme should meet acceptable intercoder reliability standards (see Chapter 3).

The following sections address each of these criteria by developing the analytic scheme relative to each of the two analytic foci: team interaction (Section 4.2) and media use (Section 4.3). I discuss the rationale for the selection of codes and coding schemes through a comparative analysis of prior coding schemes for meeting interaction.

Formula 4-1: Formalization of a model of a discrete meeting interaction analyzable as a set of behaviors in terms of its communication, reaction, action and media use component.

$$i_n = B_n = \{C_n, R_n, A_n, M_n\} = \{b_p, b_q, \ldots.\}$$

where B_n must contain at least one behavior from the set of team interaction behaviors:

$$C_n = set\ of\ communication\ behaviors\ for\ nth\ interaction$$

$$R_n = set\ of\ reaction\ behaviors\ for\ nth\ interaction$$

$$A_n = set\ of\ action\ behaviors\ for\ nth\ interaction$$

and one from the media use behaviors:

$$M_n = set\ of\ media\ use\ behaviors\ for\ nth\ interaction$$

and b_x represents a specific instance of an observable behavior from one of the interaction processes. For example, the following meeting interaction:

"What's this?" $= i_4$ = {"clarifying", "none", "doing", "utilizing"}

4.2 Interpreting Team Interaction

MIM makes distinctions between three dimensions of team interaction: communication, reaction, and action. From the literature review, I identified thirteen coding schemes that interpret behaviors related to one or more of the team interaction process concepts (Figure 2-7): ADF, AST, CDW, DEEP(AND), DRQ, GWRCS, IHF, IPA, LCA, POP, RCA, TEMPO, and SAA (see Chapter 2 and see Appendices I and J for codebooks). Studies employing these coding schemes describe differences in how teams interact. Figure 4-1 compares these coding schemes using the team interaction matrix in Table 4-1. This analysis shows that although schemes share many of the same categorical distinctions and pose similar analytic questions; no single scheme captures those distinctions for all three processes at the three levels of analysis. Table 4-2 summarizes the analysis of these schemes in relation to the MIM team interaction processes and shows that IPA and CDW come closest to capturing the MIM processes. I applied nine of these schemes to portions of meeting data. The table includes the elaboration of the "grounding" process into the processes of "describing" and "explaining" and of the "relating" process into the processes of "initiating" and "responding". The following paragraphs discuss the rationale for this elaboration and summarize the key findings from this analysis.

Table 4-1: Matrix to compare prior coding schemes to the Mediated Interaction Model of team interaction. The matrix lists analytic questions that codes answer.

Codes that answer:			
Level of Analysis	Communication 	Reaction 	Action 
Project 	Is the communication past-oriented (grounding) or future-oriented (action)? Is communication seeking rationale or explaining?	(not analyzable through observation)	Is the team acting on issues? (acting) Is the team producing information? (producing)
Process 	Is the team structuring or stating a process goal, strategy, or rule? (structuring)	Is a team member controlling? (controlling)	Is the team coordinating process or meeting activity (coordinating)?
Interpersonal Interaction 	Is the team engaging in process of communicating (relating)? Is the team communicating project information (exchanging)?	Is the team expressing (expressing, conflicting)?	Is the team initiating an issue or responding to an issue (initiating, responding)? Is the team doing project-related activity? (doing)

Table 4-2: Analysis of coding schemes relative to MIM. This shows that no single scheme analyzes meeting interaction at three levels of interaction. The IPA coding scheme interprets the widest range of multi-purpose, multi-level interaction, but is content-independent. The star symbol, ★, indicates the coding schemes that are incorporated into the final analytic scheme.

Level of Analysis	Process	Process	ADF	AST	CDW★	DEEP(AND) ★	DFCS	GWRCS	IPA★	LA	RCA★	POP★	PAC★
Project	Action	Acting				■				■			
		Producing	■		■	■							
	Reaction	Conflicting						■	■				
	Communication	Explaining[6]			■				■				
	(Grounding)	Describing	■		■	■			■				
Process	Action	Coordinating	■	■	■				■		■		
	Reaction	Controlling		■			■	■	■				
	Communication	Structuring	■		■				■		■		
Interaction	Action	Doing		■	■		■	■	■	■	■		
	Reaction	Expressing		■					■		■		
	Communication	Responding[7]							■	■	■		
	(Relating)	Initiating			■				■	■	■		
	Communication	Exchanging				■			■			■	
		Participating											■

[6] The "grounding" process comprises "grounding" and "explaining" for comparative purposes since many of the schemes distinguish between these processes.

[7] The "relating" process comprises "initiating" and "responding".

Collaborative Design Workflow (Olson et al. 1992)

	CDW
AC	Project Management
AC	Meeting Management
CS, AC	Goal
CG	Summary
CG	Walkthrough
CI	Issue
AD	Criteria
AP	Alternative
AD	Clarification
NA	Other
NA	Digression

Interaction Process Analysis (Bales 1950)

	IPA
SE	Shows solidarity
SE	Shows tension release
SE	Agrees
CD, AP	Gives suggestion
AA	Gives opinion
CG, CE, CR	Gives orientation
CG	Asks for orientation
AA	Asks for opinion
CS	Asks for suggestion
SE	Disagrees
SC	Shows tension
SC	Shows antagonism

Relational Communication Analysis (Rogers and Farace 1975)

RCA

	Response Mode
AA,CI,CR	Initiation-Termination
CS, SD	Order
AD	Extension
CI	Topic Chg
SE	Support
SC, SE	Non-Support
CR	Answer
	Disconfirm
CS, SD	Instruction
	Other
CE	Message

	Format of Message
AD	Assertion
CR, CG	Question
SD	Talk-over
	Non-complete
	Other

Decision Function Coding System (Poole and Roth 1989)

	DFCS
AD	Problem Analysis
AD	Problem critique
CS	Orientation
CG	Process reflection
CG, AD	Solution Analysis
AP	Solution design
AP	solution elaboration
AD	Solution evaluation
AA	Solution confirmation
AN	Other
AN	Tangents
RE	Agreement/Disagreement

Product, Process, and Organization (Fischer and Kunz 2005)

POP
Product
Process
Organization
Requirement
Analysis
Product-Process
Product-Organization
Process-Organization
POP
PM-NA

Activity Design Framework (Minneman 1992)

	ADF
CG	State of Artifact
CS	State of Process
CG	State of Relation
CG	Making Sense of Artifact
CG	Making Sense of Process
CG	Making Sense of Relation
AP	FF Artifact
AA	FF Process
AA	FF Relation

Language/Action (Winograd 1987)

	LA
CI	Requests
CI	Offer
AD, CR	Acknowledge
AA, CR	Commit-to-commit
AA	Promise
AD	Counter-offer
AA	Decline
AA	Report-Complete
AD	Free-form

(Liston et al. 2001, Garcia et al. 2003)

	DEEP(AND)/MIP
CG	Describe
CG	Explain
AP	Generate
AA	Predict
AA	Evaluate
AA	Analyze
AA	Negotiate
AA	Decide

Adaptive Structuration (DeSanctis and Poole 1984)

	AST
	Instrumental Use
AD	Task
AC	Process
SD	Power
SE	Social
	Individualistic
NA	Fun
NA	Confusion

Group Working Relationship (Poole and Roth 1989)

	GWRCS
AD	Focused Work
SD	Relational Integration
AD	Critical Work
SC	Opposition
SC	Accommodation
SD	Tabling
AD	Open Discussion

TEMPO (Futoran et al. 1989)

New content
Prior content
Dictate content
Process goals
Process strategies
Process acts
Agree/Disagree
Clarify/Modify
Reject/Veto
Digression

Guide to Labels

LOA	Label	**Communication**	Label	**Reaction**	Label	**Action**
Project	CE	Explaining	RC	Conflicting	AA	Acting
	CG	Grounding			AP	Producing
Process	CS	Structuring	RD	Controlling	AC	Coordinating
Interaction	CR	Responding/Initiating	RE	Expressing	AD	
	CE	Exchanging	RP	Participating	AD	Doing

Figure 4-1: Comparative analysis of coding schemes in relation to the MIM concepts using the team interaction matrix. This shows that all coding schemes capture aspects of communication and action and only three schemes capture reaction. No single coding scheme captures all aspects of team interaction at the three levels of analysis (all boxes would be shaded).

4.2.1 Communication: Exchanging, Grounding, Structuring, and Relating

The communicative perspective examines interaction as information, understanding, and relation-oriented. A meeting interaction may relate to all, none, or some of these three perspectives. For example, interaction D368 in Excerpt 4-1 involves "exchanging", "explaining", and "responding". All of the coding schemes capture at least one of these dimensions of communication. Three coding schemes, IPA, LA, and RCA, are relation-oriented and capture the process aspect of communication. These schemes, though, are content-independent and do not distinguish between an answer "giving an opinion" about a restaurant and an answer "giving an opinion" on a specific air handler assembly. The other coding schemes are content-dependent and project workflow-oriented. Four coding schemes, CDW, IPA, ADF, and DEEP(AND) are understanding-oriented, and five, CDW, DFCS, POP, ADF, and DEEP(AND) are information-oriented. No single coding scheme captures all three perspectives. The following paragraphs analyze the coding schemes in relation to MIM concepts and analytic questions.

Excerpt 4-1: Example of interpretation of meeting interaction using coding schemes that capture some aspect of communication.

		CDW	RCA	IPA	POP	DEEP	ADF	Communication Processes
W364:	What's this?	clarifying	initiate	asks for orientation	product	describe	state of artifact	exchanging + grounding + initiating
A365:	Let's look at this from the other side.	manage meeting	continue	gives suggestion	process	generate	framing process	exchanging + structuring
X366:	*((moving model))*	walkthrough	continue	NA	product	describe	state of artifact	grounding + exchanging
A367:	That's quite a bit right there.	clarifying	continue	gives orientation	product	describe	state of artifact	exchanging + explaining
D368:	I have to move it over for fire protection.	criteria	respond	gives orientation	process	explain	making sense of artifact	exchanging +explaining +responding
B369:	Which way are you moving it from the fire protection?	clarifying	initiate	asks for orientation	process	describe	state of artifact	exchanging + initiating + grounding

*Is the team communicating or **exchanging** project-related information?* Most studies of project work report the amount of time teams spend on project-related activity. The concept of *exchanging* refers to interactions that involve the exchange of project-related information. Project related information pertains to the product, process, or organization (Fischer and Kunz 2004). I use POP to classify the informational content of interactions. This is analogous to ADF's distinctions between "artifact", "relations", and "process". Most of the coding schemes implicitly reference project-related information. For example, interaction A365 discusses how the team should address an issue by moving to another model view and involves the exchange of process information. Two coding schemes, POP and ADF, explicitly reference that the interaction involves project information. The other project-oriented schemes, CDW and DEEP, implicitly reference project information.

The interpretation of what is project-related or not project-related information posed a challenge for interactions discussing features of technology or the process of using the technology. For example, in the

following interaction the team members discuss features of a specific medium and exchange information about the tool:

Excerpt 4-2: Example of team interaction: exploring media environment and its features.

G044:	(…) going to Revit.
B045:	Yeah.
G046:	It's a big step. It's a beta. Have you played around with it?
B047:	Even as far as supports, they don't have anything right now, because it is a release 1.
A048:	I was told that release 1 is likely to be available next month…at which point supports would become available. So, I think that's the timeline.

This discussion relates to the process of documenting the design and to the process of integrating design information from multiple disciplines. In Excerpt 4-3, the team members exchange information about a tool as they explore and learn features of the tool.

Excerpt 4-3: Example of team interaction: "learning" features of the media.

X139:	*((moving model and walking up to screen))*
G140:	Go to the analytic one and go to this one. Go there, go back in.
X141:	*((zooming into model))*
C142:	The middle one I understand. That's the centerline position.
G143:	Why don't you. *((hands a pen))*
A144:	Okay, so how do we do this?
G145:	So you don't have control. He has control with the pad.
A146:	Oh, no.
Z147:	*((laughter))*

These discussions also relate to the project since the team will use this new media environment in meetings. In Excerpt 4-4, the team discusses features of the media as they begin to use the tool to view a 3D model.

Excerpt 4-4: Interaction involving discussing features of media environment and the use of the media to support meeting activity.

B139	Okay, let's jump into the model. We have exciting developments on our 3D model. X has been working in parallel with the DP drawings to model this up in Revit. Uhh….
X140	*((looking at the screen))*
A141	Changes every week. *((referring to login))*
B142	So this is a live uhh…we're actually in Revit now.
A143	Uhh, what I did um was just because the Revit program is large and umm…*((someone slowed to move between drawings))*…so actually what I did this week was some screen captures so we could look at umm some different views…3D views.
A144	So what I'm going to do is walk you through the 3D views and we're going to have….

AST distinguishes these interactions from "task" or "process" as "learning". CDW and GWRCS interpret these as "tangents" or "digressing". I added a code, "managing technology", to the CDW coding scheme to distinguish these interactions from "digressing" and use POP to classify the activities as exchanging process information. This enables the interpretation of these activities as "exchanging" and as "learning" (see Section 4.3).

 *Is the communication past-oriented (grounding) or future-oriented (action)? If past-oriented, is the nature of the communication understanding-oriented or rationale-oriented?* Meetings generally act as a forum to establish a shared understanding. Meetings differ with respect to time spent developing a common ground to time spent oriented to the future. Teams rarely seek rationale—this is due in part to the need for

teams to establish a common ground before they can seek deeper understanding of the design, schedule, or project requirements. Many coding schemes distinguish interactions with respect to past- and future-oriented activity and between understanding and deeper level understanding. CD, DEEP, and ADF capture the "grounding" and "explaining" aspect of interaction. In the Phase III coding, all coders had problems distinguishing between these two types of interactions, for example, "state of" versus "making sense of" or "walkthrough" versus "criteria". For example, Coder A coded Interaction D368 in Excerpt 4-1 as "state of artifact" whereas Coder B coded it as "making sense of". To remedy this problem, I refined the definitions for the codes and instructed coders to look at coding schemes in pairs. I selected CDW, DEEP, and IPA to capture the "grounding" and "explaining" aspects of communication and incorporated ADF's definition. IPA and DEEP, though, primarily act as a validation code since CDW distinguishes between three types of grounding activities: "summary", "walkthrough", and "clarification". When the coders start interpreting interactions using three coding schemes, the reliability of the coding vastly improved.

 *Is the team **structuring**, that is, communicating project or process goals, strategies, or rules?* Teams rarely state task, project, or process goals or rules. When team members explicitly state a process goal or rule, they bring structure to the meeting. Typically, a team member instructs or orders meeting participants to do something, that is, coordinate meeting interaction. This distinction is important because teams more often coordinate than facilitate. Coordinating interactions give direction to the team and requests the team to participate and do something. Interactions that begin with "Let's…," such as interaction A365 in Excerpt 4-1, is an example. Structuring establishes the goals, purpose, and constraints for meeting interactions. CDW distinguishes between the coordinating interactions and structuring interactions with the code "manage meeting" and "goal". An example of a "goal" is "the last meeting we got most of the other trades taken care of. So, this one is going to be focused on fire protection." I use CDW to capture the structuring aspect of interaction.

 *Is the team engaged in the **relational** process of communicating?*  *Is the team **initiating** a new topic, issue, or request?*

Meeting interaction differs in the flow and rhythm of the meeting interaction at a transaction level and the informational content level. Some meetings involve constant back and forth, questions and answers, between team members whereas others involve long monologues or instructions. Some meetings address only a few issues, while others address dozens of issues. Three coding schemes, RCA, LA, and IPA, capture the transactional nature of communication and examine interaction in relation to preceding interaction, for example, "answer", "question", "response", or "request". These codes capture whether the team is engaged in the communication process, for example, initiating, continuing, or responding, as opposed to ordering, instructing, or disconfirming.

Four coding schemes—RCA ("topic change, disconfirm"), LA ("request"), CDW ("issue"), and TEMPO ("new content")—capture "switches" in communication or changes to the informational topic or issue. Switches occur in relation to moment-to-moment relational communication such as a simple request

for clarification and to project-level issues, such as a request for selecting a design option. For example, C110 in Excerpt 4-5 is a "switch" at the interaction level but does not introduce a new topic or issue. A108 is a "switch" at the project level since it introduces a new issue. This distinction is important. Some meetings involve multiple switches related to a single issue. For example, in one meeting, the identification of a problem led to a thirty-minute question-and-answer period between three meeting participants. Eventually, the team moved to another issue. In another meeting, a team identified and solved ten issues in thirty minutes.

This level of interpretation involves "chunking" to aggregate interactions that initiate or terminate a request, task, or issue. Excerpt 4-5 illustrates relational and issue "chunking" (see Excerpt 4-5) for a portion of a meeting. This chunking process takes place in three parts. First, a coder codes the segments using RCA, CDW, and IPA. Second, a coder uses an event-based custom script to segment the transcripts using the RCA and CDW codes. Third, a coder reviews the segmentation to make changes to account for any misinterpretations or coding errors. The chunking process is instrumental to examining and capturing the relational and initiating aspect of communication. The process itself yields insights into the flow, relational patterns, and rhythms of the meeting. Some meetings are easy to chunk at the interaction level and difficult to chunk at the project level. Examples are meetings that involve multiple questions and answers during the "grounding" process, such as a review meeting.

Excerpt 4-5: Example of relational analysis of a portion of a meeting. The different shades segment the interaction into relational "chunks". The CDW column shows the "issue" chunks that relate to the action aspect of the interaction.

		IPA	RCA	CDW
A108:	How do I get that sprinkler from there to there and this plumbing from here to over there?	asks for orientation	initiation	issue
C109:	…main artery there....	gives orientation	continue	clarification
C110:	How big is the other one crossing?	asks for orientation	initiation	clarification
G111:	6" and 4"	gives orientation	response	clarification
A112:	Right there we still have interference between plumbing and....	gives orientation	continue	walkthrough
X113:	*((moving model))*	NA	other	tech mgmt
A114:	Where did pens go?	asks for orientation	other	digression
G115:	Is there any chance of that tucking up into passageway? The access on the catwalk?	asks for orientation	initiation	issue
X116:	*((zooming))*	NA	other	tech mgmt
G117:	I don't see it, unless you go from stair 4 to stair 2 and then you have mezzanine system, on up….	gives orientation	continue	alternative
A118:	This graded line comes down over here has to go over to drop and this is the steel for the catwalk so they are tucked up tight as they can go to the catwalk right now and this beam has to go under. This bottom of steel is 14'-2". So, we already have 8" and 6".	gives orientation	continue	walkthrough

Other meetings are difficult to chunk at the interaction level and easy to chunk at the project level. These meetings involve a few issues but iterate through multiple questions and answers, as is, for example, typical for a conceptual design meeting. Some meetings are easy or difficult to chunk at both levels. For example, meetings that employ a clear process of reviewing items and clearly communicate closure or

resolution of an issue or a question, are easy to chunk at both levels. Some meetings move from one issue to another with participants asking more questions than giving answers and these are difficult to chunk at both levels. I use RCA to capture the interaction-level initiating process and CDW to capture the project-level initiating process.

Based on this analysis, I selected five coding schemes—CDW, IPA, RCA, DEEP, and POP—to capture the communication aspect of meeting interaction. CDW, IPA, and DEEP capture the process of "exchanging", "grounding", and "explaining" POP acts as a validation for these codes. IPA and CDW capture the "structuring" aspect of the interaction. IPA and RCA capture the relational and process dimensions of communication, "initiating and responding."

4.2.2 Reaction: Expressing, Conflicting, Controlling, and Participating

The reaction perspective examines interaction as social-, control-, and well-being-oriented. The IPA coding scheme captures all aspects of interaction.

 *Is the team **expressing** positive or negative emotion?* Teams frequently produce simple expressions of agreement and disagreement. Interpreting these interactions requires analysis of *what* as well as *how* a team member makes a statement. For example, "That's great" may be a supportive, positive statement, or it may be a negative statement made sarcastically. These differences are observable through physical gestures, intonations, expressive cues, and analysis of the context within which the interaction takes place. The IPA coding scheme makes meaningful distinctions with respect to interpreting "expressing". Excerpt 4-6 illustrates how IPA captures the "expressing" aspect of interactions A614 and H617. Preceding this sequence of interaction is a contentious discussion over a coordination problem. Team member A expresses frustration in Interaction A614 that Person H is finally agreeing to make a change and the interaction culminates this contentious period. As they discuss the issue, Person H, in interaction H617, apologizes and "shows tension release." These social expressions play a role in individual and team well-being to varying degrees. IPA sufficiently captures positive and negative expressions and makes relative distinctions between simple positive statements of agreement and expressions of tension release, such as laughter, and solidarity.

 *Is the team expressing **conflict**?* Simple disagreements can evolve into conflict and the "formation of opposing sides" (Poole and Roth 1989, p. 335). The GWRCS coding scheme captures the phases of conflict using three categories: "critical work", "opposition", and "accommodation". IPA also makes distinctions between negative expressions that "show tension" and "show antagonism". I rarely observed any conflict. I selected IPA to capture "expressing" and "conflicting" since it captures both processes.

Excerpt 4-6: Example of how IPA captures the "expressing" perspective of interaction.

	CDW	RCA	IPA	GWRCS	Reaction Processes
A614: Oh, now we are negotiating.	digression	other	shows tension	accommodation	conflicting + expressing
H615: Yeah. The wasteline will be fine. Right?	clarification	initiation	gives opinion	accommodation	
A616: The wasteline....	clarification	continue	gives orientation	accommodation	
H617: Oh, oh, sorry.	clarification	continue	shows tension release	accommodation	expressing
C618: Sprinkler drain. Sprinkler drain, right?	clarification	continue	gives orientation	focused work	

 *Is a team member* ***controlling*** *the interaction?* Meeting interaction differs relative to participation and leadership style. Controlling refers to when a team member controls the process at the expense of team or individual well-being. Controlling is difficult to interpret for a discrete meeting interaction. For example, consider interaction A690 in Excerpt 4-7. In RCA, "order" is an unqualified command and "instruction" is a suggestion. Rarely in meetings does a team member "order" another meeting participant to do something. Another interpretation of "controlling" is dominance or simply the relative portion of time that a team member speaks in the meeting. As noted in Chapter 2, this perspective is not analyzable for a discrete interaction.

Excerpt 4-7: Example of interpreting "controlling" and "structuring".

	CDW	RCA	IPA	GWRCS	**Reaction Processes**
C688: So you're keeping your standpipe high and bringing your drain where the standipe was.	summary	initiation	gives orientation	focused work	
A690: Okay, let's talk mechanical mezzanine.	manage meeting	instruction	gives suggestion	focused work	controlling ? structuring? coordinating?
A691: Do… do we have an updated (….)	clarification	initiation	asks for orientation	focused work	

Can one interpret a discrete interaction as "controlling"? "Controlling" refers to a pattern of "order" interactions or repeated "order" and "instruct" interactions. Rogers and Farace (1975) analyze the control aspect of communication by examining the sequence of interactions. Rogers and Farace use RCA to analyze control by translating the relational codes to a "control dimension." They analyze the sequence of relational codes and interpret the control dimension as a function of a sequence of codes. I applied their approach to test its feasibility and identify whether it would yield any meaningful differences in "controlling" process between two different meetings. That is, do competitive patterns of interaction relate to patterns of media use? Do differences in control relate to differences in other aspects of team interaction?

Table 4-3 shows an example of the relational control analysis for a twenty-minute portion of a meeting and shows that 4% of the interaction is "competitive" (sequence of two interactions that each seek to gain control, e.g., order, topic change) and 17% is "submissive" (sequence of interactions that support or seek support). This analysis is potentially worthwhile to analyze since dominance and control are aspects of social interaction that prior researchers relate to differences in outcome (Chapter 2). This analysis, though, requires using two coding systems and programmatic analysis (I developed a macro in Microsoft Excel to perform this analysis). The issue is that the control interpretations cannot be associated with discrete

interactions. Based on this analysis, I concluded that capturing the "controlling" aspect of interaction is not feasible and excluded the "controlling" perspective from the analytic model.

Table 4-3: Example of relational control analysis using Roger and Farace's approach. The "one-up", "one-down", and "one-across" describe the relational aspect of the interaction. For example, when a "one-up" interaction is followed by another "one-up" interaction the sequence is classified as "competitive" since both participants are exerting control.

	one-up	one-down	one-across
one-up	competitive	complementarity	transitory
one-down	complentarity	submissive	transitory
one-across	transitory	Transitory	neutralized

	one-up	one-down	one-across
one-up	4%	13%	5%
one-down	11%	17%	14%
one-across	8%	11%	12%

4.2.3 Action: Doing, Coordinating, Producing, and Acting

The action perspective examines interaction as task-, production-, and goal-oriented. All of the coding schemes capture some aspect of action. Excerpt 4-9 interprets a portion of a meeting from the action perspective using CDW, RCA, and Acting analysis. Some interactions involve "doing" whereas others involve "doing", "producing", and "responding". The following paragraphs discuss the interpretation of meeting interaction based on the four action processes: doing, coordinating, producing, and acting.

Excerpt 4-8: Example of coding to interpret "acting".

	CDW	RCA	Acting	Action
A177: You think the 10' wall is coincident with that wall on the mezzanine catwalk. That's what you are telling me?	clarification	initiation	no	doing
C178:...that's what the drawing says. Yes.	clarification	response	no	doing + responding
A179: I don't believe that is true. Because you don't have a mezzanine drawing to show me.	clarification	initiation	no	doing
C180: I have a reflected ceiling pattern that says....	clarification	response	no	doing + responding
A181: But you don't have the catwalk above it.	clarification	initiation	no	doing
Y182: *((looking at drawing))*	walkthrough	other	no	doing
A183: This is perfect.	other	other	no	none
A185: Okay. So if that's not true, can I make 10'5 ceiling coincident with that wall?	alternative	initiation	no	doing + producing
C186: Sure.	alternative	response	no	doing + producing + responding
Y187: *((looking at drawings))*	walkthrough	other	no	doing
Z188: *((various conversations, looking at drawings, whiteboard)) ((having conversations to work through issues))*	digression	other	no	none

*Is the team **doing** something related to project?* Meetings differ in the time spent focused on goal-oriented activity. The project-oriented schemes distinguish between "doing" and not doing with codes such as "digressing", "tangents", "fun", and "learning". CDW distinguishes between task-related and executive activity, the activity related to coordination of meeting activity. I interpret "doing" as task-related and executive activity and not as "learning". I use CDW to capture the "doing" aspect of action.

*Is the team **coordinating**?* Meetings differ in the time spent coordinating the meeting activity and project activity. Five coding schemes—CDW, IPA, CS, TEMPO, and ADF—capture the coordinating aspect of interaction. I selected CDW to capture "coordinating" with the two codes, "meeting management" and "project management".

 *Is the team **producing**?* Producing refers to activities that change the project artifact or process, for example, elaboration, modification, and selection of an alternative. Goldschmidt defines these interactions as "moves" (Chapter 2) or interactions that transform the design state relative to the prior state. Codes such as "generate", "alternative", and "solution elaboration" are examples of moves as are "decide" and "framing future artifact". I selected CDW and DEEP(AND) to capture the producing aspect of action.

 *Is the team **acting** on issues, requests, questions?* Meetings differ in the time spent "acting": time spent in "closed-loop" communication, beginning with an initiation, question, or issue and ending with a response, commitment, resolution, or decision. Some teams "act" at the interaction-level and fail to "act" at the project-level. A simple response to a question such as "Is that one inch?" is acting at the interaction level. Making a decision, selecting an alternative, or establishing a plan to resolve an issue is acting at the project-level.

No single coding scheme captures "acting" at both levels of analysis, and it is desirable to analyze the "acting" aspect of interaction at both levels. CWD and RCA identify the start and end events but at different levels of analysis. I use a "response" code to capture interactions that terminate a question, request, or issue at the interaction level. I developed an event-based custom script to interpret the response codes in relation to initiations. I then manually interpret whether any interaction is part of the process of resolving an issue through a decision, a commitment, or an adequate response. For example, in Excerpt 4-8, this analysis results in assigning a "no" value for this set of interactions since the initial "issue" is not resolved in the meeting. However, the coding interprets individual interactions as contributing to the processes of "doing", "responding", and "producing". In Excerpt 4-9, all of the interactions are "acting".

Excerpt 4-9: "Acting" segments for a transcript showing two levels of analysis for interpreting "acting."

	Transcript	RCA	CDW	Acting
B008:	We're supposed to find out if shaft is going to get bigger.	initiation	**issue**	
A009:	Yep. I Still don't have answer on that.	response	clarification	
B010:	That's going to be broken in 2	initiation	issue	
A011:	Did you note that anywhere on yours, D?	initiation	clarification	
D012:	I didn't.	response	clarification	
A013:	Okay.	other	other	
D014:	There's a lot of those that are going to be broken and I can't draw it….	initiation	criteria	
A015:	You can't….	continue	criteria	
D016:	So, we're not going to cut the whole thing, I'll just cut into it.	continue	criteria	
A017:	You'll just cut...	continue	clarification	
D018:	Yeah. Along the bottom	response	clarification	
A019:	So they need the wires.	initiation	**issue**	
D020:	Yeah.	response	clarification	
A021:	Okay	other	clarification	
A022:	C did we just move the pipe out of the way here.	initiation	issue	
C023:	Yes I did.	response	clarification	
A024:	On the other side?	initiation	clarification	
C025:	Moved it.	response	clarification	

4.2.4 General Issues of Interpretability

The design of a coding scheme must balance issues of reliability and interpretability with creating categories and codes that make meaningful distinctions in the behaviors. Two types of interaction posed interpretation challenges: non-verbal communication and simple utterances such as "Okay" and "Yes."

(A) Non-verbal communication. None of the prior coding schemes explicitly addresses how to interpret periods of non-verbal communication. All meetings I observed had intermittent and sometimes lengthy periods of non-verbal communication. During these periods, teams may silently review drawings, video, or private documents or reflect on a question or issue. For example, one meeting had a lengthy period of four team members drawing and reviewing conceptual designs. Interpreting these interactions as "other" or "digressing" would fail to capture meaningful activity. Likewise, one meeting had a lengthy period of silence during which team members were working separately and trying to resolve a disagreement. The final coding scheme reflects interpretation of these activities using coding categories to reflect the communicative, active, and reactive aspects of the non-verbal activity. For example, in Excerpt 4-10, the coder interprets a silent period involving a participant marking up the model (X109) as "alternative" and "continue" since the activity is related to generating an alternative solution to the current design. The coder interprets Activity X112 as "walkthrough" and "communicate" since the team completes generating the alternative and moves to review the design. The code "communicate" is a modification to the RCA coding scheme to label activity that does not relate to an issue, does not initiate, continue, or respond.

Excerpt 4-10: Example of interpreting non-verbal communication.

		CDW	RCA	IPA
A108	This is going to be moved down to here. Draw a line right across here.	alternative	initiate	gives suggestion
X109	*((marking up model))*	alternative	continue	NA
A110	Just draw a line right across there.	clarify	continue	gives suggestion
X111	*((marking up model))*	alternative	respond	NA
X112	*((review of model))*	walkthrough	communicate	NA

(B) Simple utterances. Meeting interaction includes lengthy speaker turns, and short, simple utterances, such as "Okay", "Yep", and "Yeah". These utterances are typically brief, taking their meaning from the context and sequence of interactions within which they occur. "Yes" can be a confirmation, a clarification, a response, or a simple agreement. The use of multiple coding schemes allows for multiple interpretations of these simple utterances from the various levels and purposes of interaction. For example, consider the simple statement "Yeah" in the following excerpt.

Excerpt 4-11: Example of multiple interpretations of a simple statement (D228) as "clarification", "response" and "gives orientation."

Segment	Transcript	CDW	RCA	IPA
X225	*((reviewing model))*	walkthrough	other	NA
A226	All right. Let's go down.	manages	order	gives suggestion
X227	*((walking through model))*	walkthroughs	other	NA
A227	(…) Okay with that?	identifies issue	initiate	asks for orientation
D228	Yeah.	clarify	respond	gives orientation

The "Yeah" utterance (Excerpt 4-11) clarifies the previous issue, responds to a request (initiation), and "gives orientation". This simple utterance and its preceding utterance demonstrate how quickly a team can review a model, identify an issue, and adequately respond by confirming. In the following interaction, Excerpt 4-12, the coder interprets "Yep" as "Agrees" because the speaker is agreeing to make the change in "response" to the instruction to mark up the "alternative".

Excerpt 4-12: Example of interaction including a simple utterance, "Yep."

A218	Actually, H. Erase that. Show it like this. What they'll do is take the rungs out of the cable tray.	alternative	instruct	gives orientation/ gives suggestion
W219	Yep.	alternative	respond	agrees

Simple utterances illustrate the inherent challenges of interpreting interaction and the possibility for multiple interpretations. I address this issue by using multiple coding schemes. This allows for the interpretation of any interaction from multiple perspectives. For example, CDW does not sufficiently capture nuances in interaction at this level of granularity. Thus, the coder interprets these simple statements in relation to the preceding or following interaction. For example, in this case it continues the process of creating the alternative design solution. On the other hand, RCA captures nuances in communication at this level of granularity.

Due to these challenges, I made several modifications to the coding schemes and coding instructions. I instructed coders to use IPA to capture the reaction aspect of simple statements, since the other two schemes capture the communicative and action aspect. I instructed coders to use the code "gives orientation" instead of "agrees" or "disagrees" when the meeting interaction is in direct response to a request.

4.2.5 Reliability

The reliability calculations narrowed the selection of the coding schemes to five coding schemes (Table 4-4). GWRCS and AST did not meet acceptable intercoder reliability standards and did not meet the usability and interpretation criteria, so I excluded them from further analysis after Phase III (see description of phases in Chapter 3). I also excluded ADF from further analysis since CDW and DEEP duplicate its coding categories. DEEP had unacceptable reliability in Phase III primarily due to distinguishing between "describing" and "explaining". I modified the code definitions of DEEP, incorporating aspects of POP, to capture the informational exchange aspect of the meeting interaction. I also established checks and balances using CDW to improve the reliability of DEEP. For example, if a coder interprets an interaction as "describe" then the code for CDW should be "clarify", "walkthrough", or "summary". I also simplified the coding scheme to focus on its use in relation to project information. I renamed this coding scheme Media Instrumental Purpose (MIP) (see Section 4.4.1) to distinguish it from DEEP(AND). Similarly, POP had low reliability values in Phase III due to challenges with distinguishing information as product, organization, and process, and this led to creating categories that are combinations of these. Ultimately, these distinctions are not meaningful but act as a check for DEEP and CDW. Thus, I incorporated aspects of POP into both

MIP and CDW. If the interaction is not associated with either product, organization, or process information, then none of the DEEP codes apply and either the code, "digression" or "other" applies for CDW. CDW, RCA, and IPA met acceptable intercoder reliability standards.

Table 4-4: Intercoder reliability values for the team interaction coding schemes applied to the observations in Phase III and Phase IV. The table lists the percent agreement (PA), Krippendorff's Alpha (α), and Cohen's Kappa (κ). In Phase IV, I modified several schemes and excluded several schemes due to low reliability calculations. Shaded dark grey values did not meet acceptable standards. Values in bold lettering met high intercoder standards. Values in medium grey met acceptable standards.

	Phase III				Phase IV			
Scheme	PA_{III}	α_{III}	κ_{III}	Scheme	PA_{III}	α_{III}	κ_{IV}	average across phases $avg(\alpha_{III}+\kappa_{III}+\alpha_{IV}+\kappa_{IV})$
CDW	**0.84**	0.68	0.70	CDW	**0.94**	**0.92**	**0.92**	**0.81**
IPA	**0.85**	0.79	0.79	IPA	**0.93**	**0.92**	**0.92**	**0.88**
RCA Form	**0.96**	0.90	0.90	RCA	**0.91**	**0.89**	**0.89**	**0.90**
RCA Response	**0.90**	0.86	0.86					**0.86**
GWRCS	0.68	0.36	0.30					0.33
AST SOS	0.75	0.34	0.28					0.31
AST IU	**0.92**	0.55	0.66					0.60
ADF	**0.91**	**0.87**	**0.87**					**0.87**
DEEP	**0.86**	0.72	0.72	MIP	**0.97**	**0.96**	**0.96**	**0.84**
POP	**.65**	.45	.45					

4.2.6 Team Interaction Analytic Schemes

Many prior researchers share the concepts I selected to examine using MIM. CDW and IPA come closest to capturing all of the MIM concepts. Based on the analyses and the reliability calculations, I selected four coding schemes, CDW, IPA, RCA, and DEEP, to capture the aspects of team interaction identified in MIM. The CDW scheme captures the information, understanding, and production-oriented aspects of interaction. I made one modification to CDW, adding the category "managing technology" to address this issue noted in the previous section. I renamed the scheme as Collaborative Workflow Analysis (CWA) to apply more generally to design and construction meeting interactions. IPA captures the reaction-oriented aspects and acts as a validation code for relational and information-oriented codes. RCA captures the relational level of interaction that the other coding schemes do not capture as well as another level of interpretation for "acting". The original RCA consisted of three sets of codes and I chose to use only the response set of codes. I refer to this modified version of RCA as the Relational Workflow Analysis (RWA) coding scheme. I added one code, "communication", to represent an interaction that is not part of the relational process, but merely an interaction that communicates something, e.g., a goal or summary and is not a direct response to a previous interaction or an initiation. Table 4-5 summarizes the MIM processes, coding schemes, and specific code categories. Table 4-5 also includes the analytic questions for each MIM process and examples of interactions associated with the MIM concept.

Table 4-5: Summary of MIM team interaction processes and their association to analytic questions and the MIA team interaction coding schemes. Table includes examples of interactions representing each process.

Level of Analysis	Process	Process	Analytic Question	Codes	Example	CWA (modified version of CDW)	MIP (DEEP(AND))	IPA	RWA (modified RCA)
Project	Action	Acting	*Is team resolving or adequately responding to requests or questions?*	responding, give orientation, terminate	*No, I can do something. I'll forward you the e-mail, Yeah, we're all set.*		■		■
		Producing	*Is team producing project information?*	alternative, generating, predicting, evaluating	*What if you moved cable tray over slightly?*	■	■		
	Reaction	Conflicting	*Is team expressing antagonism or solidarity?*	show tension, show antagonism	*No one is listening to me.*			■	
	Communication	Explaining	*Is team seeking rationale? Criteria?*	explaining, criteria	*He has to stay under the beam. He can't go back up. He has to be below the bottom.*	■	■		
		Describing	*Is team taking stock of past or current project states? (product, organization, or process)? Is team describing or explaining?*	describing, walkthrough, summary, criteria, gives orientation, clarification	*Is that 1"? What is this? Heating water?*	■	■	■	
Process	Action	Coordinating	*Is team coordinating meeting activity?*	manage meeting	*Let's take care of one problem at a time. Then we'll go back to the horseshoe.*	■			
	Reaction	Controlling	*Is a meeting participant controlling meeting activity?*	order, instruct, give suggestion	*Well, let's take care of your cable tray first.*				■
	Communication	Structuring	*Is team structuring meeting activity? Communicating goals, strategies, rationale for process?*	give suggestion, goal	*The last meeting we got most of the other trades taken care of. So, this one is going to be primarily focused on fire protection.*	■		■	
Interpersonal Interaction	Action	Doing	*Is team activity related to project? Product? Process? Organization?*	digressing	*Boy, this stuff is making me dizzy . Is that a bar/restaurant?*			■	■
	Reaction	Expressing	*Is team expressing emotion? Positive, negative?*	agree, disagree, show tension release	*((laughter)), That's great.*			■	
	Communication	Responding	*Is team responding to an issue or question?*	respond, answer, terminate	*No, I can't get any lower.*	■			■
		Initiating	*Is team initiating a question or issue?*	issue, initiate, question	*looks like it's looks like it's missing everything there*	■			■
		Exchanging	*Is team exchanging project information?*	describe, explain, generate, evaluate, predict	*The bottom is 14'. You got a 13'3" ceiling.*		■		

4.3 Capturing Media Use: Use, Interactivity and Purpose

From the literature review, I identified fifteen coding schemes with a focus of analysis related to at least one or more of the media use concepts (see Chapter 2; see Appendices J and K for codebooks). The analysis uses the media use matrix (Table 4-6) for comparative analysis. This analysis shows that schemes share many of the same categorical distinctions, but are limited to examining one aspect of media use.

Table 4-7 and Figure 4-2 summarize the analysis of these schemes in relation to the MIM media use concepts. I applied five of these schemes to portions of meeting data (see sample in Table 4-8). The following paragraphs summarize the key findings from this analysis.

Table 4-6: Matrix to compare prior coding schemes to the Mediated Interaction Model of media use.

Level of Analysis	Use	Interactivity	Purpose
Project	Is the team sharing media?	Is the team directly interacting with the media?	Is the team using media to produce? Act?
Process	Is the team transitioning from private to shared media?	Is the team integrating media into process?	Is the team using media to coordinate?
Interpersonal Interaction	Is the team using media? If so, what type?	Is the team engaging with media?	Is the team using media to communicate?

Table 4-7: Summary of analysis of coding scheme in relation to MIM media use processes and levels of analysis. This analysis shows that prior coding schemes do not capture periods when media use is "performing", "integrating", or "transitioning". It also shows the emphasis of capturing media use at the interaction level or project level.

Level of Analysis			IR	MMI	Use by Type (MUT)	Access (MUA)	PP	AI	AIG	MG	FWA	Interactivity (MUI)	GAI	AST	DEEP(AND)	POP	FWA
Project	Purpose	Producing											■	■	■		■
	Interactivity	Changing								■		■					■
		Annotating		■				■	■	■	■		■				■
	Use	Performing															
		Sharing										■					
Process	Purpose	Coordinating											■	■			■
	Interacting	Transitioning															
	Use	Integrating					■			■							
Interpersonal Interaction	Purpose	Communicating	■										■		■	■	■
		Learning												■			
	Interactivity	Referencing				■	■	■	■	■	■	■	■				■
		Viewing				■	■	■	■	■	■	■	■				■
	Use	Supporting	■	■	■		■	■	■	■	■	■	■	■	■		■
		Utilizing	■	■	■						■			■			■

Use and Type

Information Richness (Daft and Lengel 1984)	Multi-Modal Meeting Interaction (McCowan 2005)	Media Use by Type and Source (Liston et al. 2007)
IR	**MMI**	**MUT**
Channel	Monologue	None
Audio	Presentation	Digital
Visual	White-board	Paper
Sensory	Discussion	Whiteboard
Source	Note-taking	Physical Model
Personal		Conceptual
Impersonal		

Access

Access (Liston et al. 2007)
MUA
Single
Private
Semi-Shared
Shared

Interactivity and Gestures

Pointing (Clark 2003)	Goals of Artifact Interaction (Tory et al. 2008)	Goals of Artifact Interaction (Tory et al. 2008)	Meeting Gestures (Bekker et al. 1995)	Framework for Analyzing Workspace Activity (Tang 1989)	Interactivity (Liston et al. 2007)
PP	**AI**	**GAI-1**	**MG**	**FWA**	**MUI**
Describing as	Gesture	Pointing	Kinetic	List	Viewing
Demonstrating	Navigate	Covering	Spatial	Draw	Pointing
Indicating	Annotate	5-finger pointing	Point	Gesture	Annotating
	View	Segment indication	Other		Changing
Directing to		2-finger indication			
Placing For		Parallel indication	Walkthrough		
		Interval	List sequence		
		Outlining	Contrast sequence		
		Spatial move	Emphasis sequence		

Purpose

Goals of Artifact Interaction (Tory et al. 2008)	Adaptive Structuration (DeSanctis and Poole 1984)	Information Use (Liston et al. 2001, Garcia et al. 2003)	Communicative Functions (Hendry 2004)	Framework for Analyzing Workspace Activity (Tang 1989)
GAI-2	**AST**	**DEEP(AND)**	**CF**	**FWA**
Visualize	Instrumental Use	Describe	conscripting	Store
Attract attention	Task	Explain	coordinating	Express
Direct attention	Process	Generate	framing	Mediate
Lookup	Power	Predict	persuading	
Describe	Social	Evaluate	recording	
Query	Individualistic	Analyze		
Relate	Fun	Negotiate		
Prepare	Confusion	Decide		

Level of Analysis		**Use**		**Interactivity**		**Purpose**
Project		Performing		Changing		Producing
		Sharing		Annotating		
Process		Integrating		Transitioning		Coordinating
		Supporting		Referencing		Communicating
Interpersonal Interaction		Utilizing		Viewing		Learning

Figure 4-2: Comparison of prior media use schemes in relation to MIM concepts. No single scheme describes the three aspects of media use at the three levels of analyses. Collectively, the schemes describe these aspects of media use.

 *Is the team **utilizing** any media? If so, what type*? Many of the coding schemes apply only to interactions involving media and do not explicitly distinguish between interactions that use media. The Information Richness coding scheme (IR) distinguishes between personal and impersonal sources of communication. In prior research I developed a "Media Use by Type" (MUT) coding scheme that distinguishes between personal (conceptual) and impersonal sources and further distinguishes between the type of media source, digital, paper, or whiteboard. For example, when a team member discusses a code requirement without reading, pointing, or referring to a document in the room, this is classified as "personal". Whereas, if the participant points to a code book, or note on a drawing, the source is "paper". It also includes a category "none" to denote interaction that does not communicate project information. In Table 4-8, for example, the coded data from this scheme captures whether the team is "using" or not using media.

One of the notable gaps with prior schemes is distinguishing interactions that involve the use of media with verbal communication from those involving use of media with no verbal communication. For example, in Excerpt 4-13, interactions X093 and X096 involve interaction with a digital model and viewing of the model with no verbal communication by any team member. I refer to these periods as "performing" and refer to the interactions involving verbal communication and media use as "supporting." This distinction is meaningful as it distinguishes the use of media in many of the meetings I observed. Some teams let the media do the communicating for them whereas others use the media to support their communication.

Excerpt 4-13: Excerpt showing period of media use not captured by existing coding schemes.

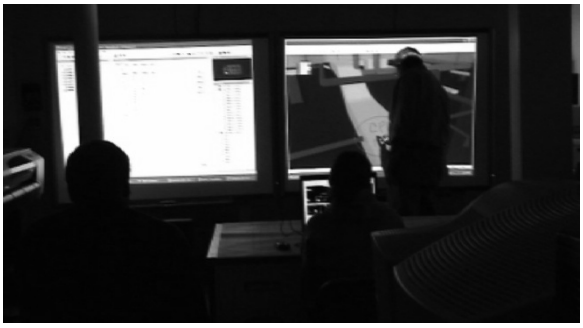
Transcript Segment		**Utilizing**
F091:	Where do you want to start?	supporting
A092:	Let's start in that corner there.	supporting
X093:	*((moving to view)) ((turn walls off))*	performing
A094:	Let's fly. Let's grab onto the cable tray wherever it starts.	supporting
Z095:	Is that it right there?	supporting
X096:	*((flying through model))*	performing

 *Is the team **sharing** media?* I also developed a coding scheme, *Access*, to capture whether the media is accessible to all meeting participants (sharing) (Figure 4-3[B, D]), a portion of the meeting participants (semi-sharing) (Figure 4-3[A and C]), to all meeting participants but as a private document (private) (Figure 4-3[E]), or to only one meeting participant. Prior studies conceptualized this aspect of media use but did not develop a coding scheme. Table 4-8 shows the moment-to-moment changes in access that occur in meetings as teams switch focus from a public model to a set of drawings in front of a portion of the team. These changes in access also signal periods of "transitioning". I did not develop a coding scheme to note when transitions took place. Instead, I analyze "transitioning" programmatically using the Access and IT coding schemes (Appendix J.9). The IT coding scheme is a list of different documents in

each meeting, such as 2D drawing, schedule, and model. When there is a change from one type of media to another type of media or a change from type of access to another type of access, a transition occurs.

*Is the team **interacting** with media? If so, how?* I developed a coding scheme to capture levels of interactivity, building on codes found in other coding schemes, such as PP, AI, AIG, FWA, and MG. The scheme captures the different levels of engagement with the media that relate to "directing" or directing the team's attention to media using "pointing" (Figure 4-3[A]), "expressing", or capturing ideas of the team through annotation of the media (Figure 4-3[B]), and "working" or making changes to the media content or form (Figure 4-3[D]).

(A) Pointing, shared



(B) Annotating, shared

(C) Pointing, semi-shared

(D) Changing, shared

(E) Viewing, private

Figure 4-3: Examples of different aspects of media use including dimensions of access and interactivity.

*What is the instrumental **purpose** of media use?* Several of the coding schemes capture the instrumental purpose of media. No single coding scheme captures the multiple purposes of media use. The DEEP(AND) coding scheme captures eight purposes of media use (describe, explain, generate, evaluate, predict, analyze, negotiate, and decide) but it does not capture the coordinative function of media use that the communication function coding scheme captures. The CDW coding scheme captures when the team is coordinating. I combine the CDW code with the utilizing code to capture the coordinative purpose of media use.

Table 4-8: Example of media use coded data.

	Media Use by Type (MUT)	Interactivity (MUI)	Access (MUA)	POP	DEEP (MIP)	IT	Transition	Media Use
A179: I don't believe that is true. Because you don't have a mezzanine drawing to show me.	digital	viewing	sharing	product	describing	3D model	no	using + supporting + communicating
C180: I have a reflected ceiling pattern that says...	paper	viewing	semi-sharing	product	describing	2D drawing	yes	using + supporting + transitioning
A181: but you don't have the catwalk above it	paper	viewing	semi-sharing	product	describing	2D drawing	no	using + supporting + communicating
Y182: *((looking at drawing))*	paper	viewing	semi-sharing	product	describing	2D drawing	no	using + performing
A183: This is perfect.	digital	pointing	sharing	product	describing	3D model	yes	using + directing + transitioning
A185: Okay. So if that's not true, Can I make 10'5 ceiling coincident with that wall?	paper	viewing	semi-sharing	product	generating	2D drawing, 3D model	no	using + directing + acting
C186: Sure.	paper	viewing	semi-sharing	product	evaluating	2D drawing	no	using + supporting + producing
Y187: *((looking at drawings))*	paper	viewing	semi-sharing	product	describing	2D drawing	no	using + performing
Z188: *((various conversations, looking at drawings, whiteboard)) ((having conversations to work through issues))*	none	none	NA	NA	NA	2D drawing	yes	

4.3.1 Media Use Analytic Schemes

I selected four coding schemes based on this analysis to interpret the media use perspective of meeting interaction—Use by Type (MUT), Access (MUA), Interactivity (MUI), and DEEP (MIP)—to capture the aspects of media use identified in MIM. The Use by Type scheme captures the use aspect of media use in terms of utilization and modality. Access captures the use aspect in terms of accessibility of the media to the meeting participants. The "transitioning" aspect of media use is analyzable using these two codes. Interactivity captures the interactivity aspect of media use, ranging from no level of engagement with media to physical interaction with the media and its content. DEEP and CDW capture the instrumental purpose of media use. I made modifications to DEEP to code interactions in terms of the media content and to address reliability problems with the inclusion of "negotiate", "analyze", and "decide". These codes pertained to team interaction functions and CDW and IPA capture this aspect of the interaction. Thus, from the media use perspective, DEEP only applies to interactions when the team is using media, and the labels

describe whether the team is "_____ project information", i.e., describe project information, explain project information, evaluate project information, or generate project information. I renamed DEEP(AND) to Media Instrumental Purpose (MIP) coding scheme to distinguish it from the prior coding schemes. CDW captures the coordinative instrumental purpose of media use.

These media use coding schemes met the intercoder reliability standards (Table 4-9). Table 4-10 summarizes the relationship between the MIM processes, the media use coding schemes, and specific code categories. Table 4-10 also includes the analytic questions for each MIM process and examples of interactions associated with the MIM concept.

Table 4-9: Intercoder reliability values for the media use coding schemes applied to the observations in Phase III and Phase IV. The table lists the percent agreement (PA), Krippendorff's Alpha (α), and Cohen's Kappa(κ). In Phase IV, I modified the DEEP and POP coding scheme due to low reliability calculations. Shaded dark grey values did not meet acceptable standards. Values in bold lettering met high intercoder standards. Values in medium grey met acceptable standards.

	Phase III				Phase IV			
Scheme	**PA_{III}**	**α_{III}**	**κ_{III}**	**Scheme**	**PA_{III}**	**α_{III}**	**κ_{IV}**	**Average Across Phases** avg(α_{III}+ κ_{III}+α_{IV}+ κ_{IV})
DEEP	**0.86**	0.72	0.72	MIP	0.97	0.96	0.96	**0.84**
Access	**0.91**	0.69	0.69	Access (MUA)	0.97	0.91	0.90	0.79
Interactivity	**0.89**	0.67	0.67	Interactivity (MUI)	0.99	0.99	0.99	**0.83**
Media Use by Type				Media Use by Type (MUT)	.96	.90	.90	**.90**
POP	0.65	0.45	0.45					0.45

Table 4-10: Summary of MIM media use processes and their association with analytic questions and the MIA media use coding schemes. Table includes examples of interaction representing each process.

Level of Analysis	Aspect	Process/ Behavior	Analytic Question	Example	MUT	MUA	MUI	MIP	CWA
Project	Purpose	Producing	Is team using media as a workspace to produce project information, add, or modify?	*"I think putting parking here and balance that and get up…" ((pointing and drawing))*	■			■	■
	Interactivity	Changing	Is team changing the content of the medium?	*((drawing))*	■		■	■	
		Annotating	Is team adding information to the medium?	*"Okay. G, show this cable try right in the back starting its radius. Back here and bringing right on the other side of that flange." ((as G marks up the model))*	■		■	■	
	Use	Performing	Is the primary communication, the media? Is the media performing the communication?	*"You can't see it but you can see there is roofing going on right now. ((silence while watching construction schedule)) "These are floating floors right here."*	■				
		Sharing	Is team using shared media?	(See Figure 4-3 for comparisons of shared, semi-shared, and private)	■	■		■	
Process	Purpose	Coordinating	Is the team using media to coordinate and manage meeting activity?	*"All right. Uhh…so we got fire protection done, electrical done, HVAC piping done, sheet metal course, plumbing we picked up the whole way through…Let's go hit all the viewports." ((referencing digital set of images))*	■				■
	Interactivity	Transitioning	Is team transitioning from one medium to another?	*"Probably not a bad idea to look at the details for that. Yeah, let's do that. ((*switch to details*))"*	■	■	■		
	Use	Integrating	Is team integrating media use into process? Is some or all of the team using the media?	*" The outpatient pharmacy…which is next to the gift shop needs to be umm…occupied at the same take as intake and day hospital…this area here (pointing to paper near end of table)"*	■	■			
Interpersonal Interaction	Purpose	Communicating	Is team using the media to communicate project information? If so, what type of information? (use POP as check)	*"Yeah. I understand it's bolted into the side walls and the HSS" ((while pointing at detail on digital display))*	■			■	
		Learning	Is team learning to use the media? Learning features of the media or exploring the media?	*"It's a big step. It's a beta. Have you played around with it?"*	■				
	Interactivity	Viewing	Is interacting with media engaging one or some portion of the meeting?	Pointing or viewing media.	■	■	■		
		Supporting	Is team using media to *support* verbal communication?	Talking over a video or image, viewing	■		■	■	
	Use	Utilizing	Is the team *using* any media? If so, is the team using more than one media? What type of media? Is the team communicating or exchanging project information (any of the POP information)?	*((watching snapshots))* *"This is all your piping, right here, right?" ((referring to 3D model))* *"I believe so. I think I had one cloud with a minor hit."* *"it's supposed to go to OSHPOD by the 18th"*	■	■	■	■	

4.4 Mediated Interaction Analytic Scheme

Based on the comparative analysis, review of literature, application of schemes to observational data, and reliability measures, I selected seven coding schemes that constitute the Mediated Interaction Analytic Scheme (MIA coding scheme). MIA, as shown in Figure 4-4, integrates three prior coding schemes—CWA (modified CDW), RWA (modification to RCA), IPA—with four coding schemes that I developed during this research—Media Use by Type (MUT), Access (MUA), Interactivity (MUI), and Media Instrumental Purpose (MUP). MUP and CWA coding schemes incorporate POP into the code definitions. All coding schemes met acceptable standards for intercoder reliability as listed in Table 4-4 and Table 4-9. Each coding scheme includes categories that map to MIM constructs, and each MIM construct maps to two coding schemes or two coding categories (Table 4-11). This feature of MIA improves reliability and usability to allow for multiple interpretations and for coders to perform checks and balances during the coding process. The codebook for the MIA Analytic Scheme is included in Appendix K and lists descriptions of each coding category.

Table 4-11: Mapping of MIM constructs to MIA coding schemes. The table shows the use of multiple coding schemes to interpret and capture meeting interaction from a focus of analysis. This supports validation of the scheme and interpretation of a range of meeting interaction from multiple perspectives.

Level of Analysis	TEAM INTERACTION PERSPECTIVE			MEDIA USE PERSPECTIVE		
	Communication	**Reaction**	**Action**	**Use**	**Interactivity**	**Purpose**
Project	**Explaining** (CWA+ MIP)		**Acting** (*RWA+CWA+ DEEP)	**Performing** (MUT + MIP)	**Changing** (MUT + MUI)	**Producing** (MUT + MIP +CWA)
	Describing (CWA+ IPA+MIP)		**Producing** (CWA+MUP)	**Sharing** (MUT + MUA)	**Annotating** (MUT + MUI)	
Process	**Structuring** (IPA+CWA)	**Conflicting** (IPA)	**Coordinating** (CWA +IPA+RWA)	**Integrating** (MUT + MUA)	**Transitioning** (MUT + MUA*)	**Coordinating** (MUT+ CWA)
Interpersonal Interaction	**Relating (Initiating/ Responding)** (CWA+RWA)	**Expressing** (IPA)	**Initiating/ Responding** (CWA+MIP)		**Directing** (MUT + MUI)	**Communicating** (MUT + MIP + CWA)
				Supporting (MUT +CWA + MIP)		**Learning** (MUT+ CWA)
	Exchanging/Doing (CWA+MIP)			**Utilizing** (MUT +)		

Mediated Interaction Analytic Scheme

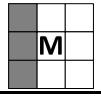
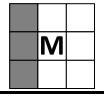
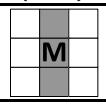
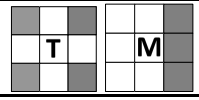
Team Interaction			Media Use			
Collaborative Workflow (CWA)	**Relational Workflow (RWA)**	**Interaction Process Analysis (IPA)**	**Media Use by Type (MUT)**	**Access (MUA)**	**Interactivity (MUI)**	**Media Instrumental Purpose (MIP)**
						
• *Is the team focused on the project?* • *Is the team looking forward or backward?* • *Is the team focused on product, organization, or process?*	• *Is the team initiating a new topic or issue?* • *Is the team responding to a topic or issue?* • *Is the response closed-loop?*	• *Is the team reacting positively or negatively to one another?*	• *Is the team using media, and if so, what type?*	• *Is the team using shared, semi-private, or private media?*	• *Is the team interacting with the media? If so, are they viewing, pointing, annotating, or changing?*	• *Is the team using the media to communicate project information? If so, past, current or future information?*
project management	initiation	shows solidarity	digital	single	viewing	describe
meeting management	order	shows tension release	paper	private	pointing	explain
goal	continue	agrees	whiteboard	semi-shared	annotating	generate
summary	response	gives suggestion	physical model	shared	changing	predict
walkthrough	disconfirmation	gives opinion	conceptual			evaluate
issue	response-initiation	gives orientation	none			
criteria	communication	asks for orientation				
alternative	other	asks for opinion				
clarification		asks for suggestion				
other		disagrees				
digression		shows tension				
technology management		shows antagonism				

Figure 4-4: The Mediated Interaction Analytic Scheme comprising seven coding schemes. The chart shows the relation of each coding scheme to the MIM framework and lists the primary analytic questions answered by each scheme. The MIM framework boxes indicate the aspect of MIM that the coding scheme captures. Collectively, the seven coding schemes capture the key aspects of team interaction and media use at the three levels of analysis: project, meeting process, and interpersonal interactions.

4.5 Findings Using MIA: Commonalities, Differences, and Patterns of Meeting Interaction

As evidence for the generality and power of the MIA analytic scheme, I applied MIA to nine meetings to capture differences and commonalities in meeting interaction from two perspectives: team interaction and media use. The following sections discuss the key findings from applying MIA to nine meetings from the perspective of each MIM analysis: communication, reaction, action, and media use. I examine the team interaction and media use processes from each categorical perspective and then conclude with a discussion of overall insights into the team interaction process, media use process, and mediated interaction process. The results serve three purposes beyond validation of the MIA scheme. First, the results from proportional, rate, and keyword maps act as a basis to identify characteristics of typical and atypical interaction and media use. The findings point to several characteristics of typical team interaction but do not point to characteristics of typical media use. I identify several patterns of "relating," "coordinating," "accessing," and "interacting." The proportional and rate analyses do not sufficiently capture these processes. Second, the individual categorical analyses do not fully capture the richness of the interaction. Third, the results demonstrate the shortcomings of existing methods to describe and compare team interaction and media use.

4.5.1 Team Interaction

The proportional analysis for each MIM process shows a wide range of team interaction. Table 4-12 summarizes the proportional analysis data for each MIM category of analysis. Teams differed in all aspects of team interaction, with the greatest difference in time spent "acting" and the smallest difference in time spent "expressing." Typical meeting interaction is exchanging (focused), grounding and discussing artifact-related information, and working towards a resolution ("acting"). Atypical interaction is conflict, overt positive or negative expression, and communication of process goals or organizational issues.

Table 4-12: Analysis of time teams spent for the team interaction behaviors showing the average time spent and range of time teams spent. Since each interaction may involve behaviors related to multiple team interaction processes, the values in the "Average" column do not sum to 100%.

			% of Meeting Time Team Spends…				
Level of Analysis	Team Interaction Process	Team Interaction Behavior	Average $\bar{x}$	Standard Deviation σ	Minimum	Maximum	Range
Project	Action	Acting	69.7%	0.15	47.7%	91.7%	44.0%
	Action	Producing	10.3%	0.12	0.5%	36.5%	36.0%
	Communication	Explaining	10.4%	0.05	2.9%	18.7%	15.8%
	Communication	Grounding	49.6%	0.13	32.4%	70.3%	37.9%
Process	Action	Coordinating	10.2%	0.06	3.8%	20.9%	17.1%
	Reaction	Conflicting					
	Communicating	Structuring	9.2%	0.04	5.9%	18.0%	12.1%
Interaction	Communication/ Action	Responding	28.6%	0.15	15.5%	59.2%	43.7%
	Communication/ Action	Initiating	29.5%	0.09	20.4%	46.4%	26.0%
	Reaction	Expressing	4.4%	0.02	1.3%	8.9%	7.6%
	Action	Doing	85.7%	0.12	64.2%	96.9%	32.7%
	Communication	Exchanging	93.3%	.03	88.0%	98.2%	10.2%
							$\bar{x} = 27.3\%$

Exchanging. Teams spent a majority of the time discussing artifact-related information and exchanging project-related information and little time discussing organizational issues. Teams spent, on average, 93.3% of the time exchanging and communicating about project-related information. Two teams spent approximately 30% of the time discussing media features and media processes (Figure 4-5). Teams exchanged product-related information 88% to 98% (σ = .09) of the time, process-related information 8% to 24% (σ = .24) of the time, and organizational information 1%-8% (σ = .03) of the time. These differences in information content are attributed to the different types of meetings. Conceptual design meetings primarily involve interactions exchanging artifact information whereas schedule review meetings primarily involve interactions exchanging process and artifact information. Teams devoted little to no attention discussing organizational issues.

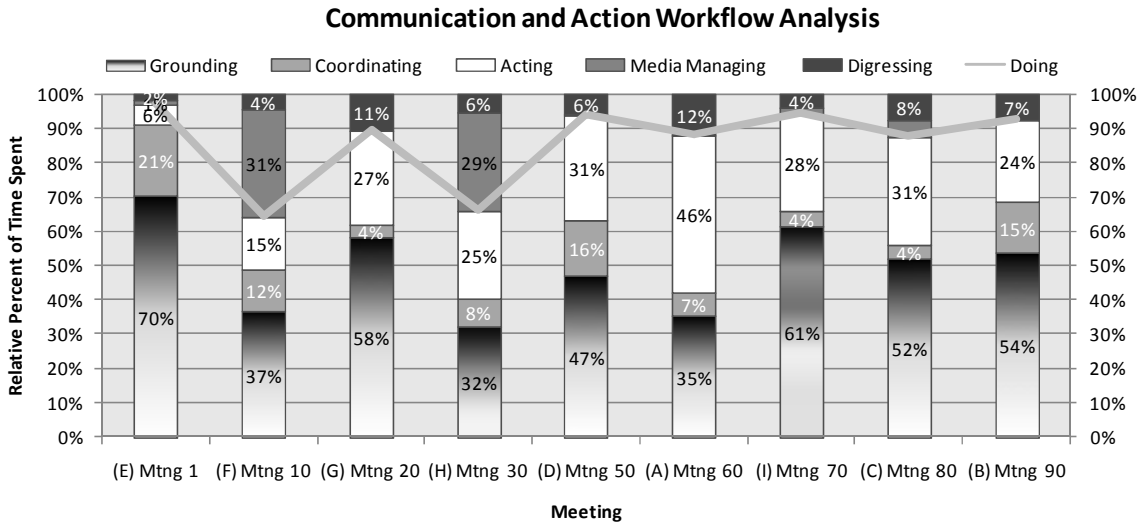


Figure 4-5: Comparison of observations using the workflow perspective. This chart shows the differences across observations in the time spent managing the process and project, focusing on product-related activity, taking stock, or "grounding".

Grounding and Explaining. Teams spent significantly more time "describing" than "explaining". Teams spent 32% to 70% ($\bar{x} = 50\%, \sigma$ = .10) of meetings "grounding" and 3% to 19% ($\bar{x} = 10\%, \sigma$ = .05) "explaining." As a percentage of time spent communicating project-related issues, teams spent from 68% to 96% of the time grounding. These findings are similar to those by Olson et al. (1992) and Liston et al. (2001) and confirm the notion that meetings act as a forum to establish a shared understanding or common ground (Clark and Brennan 1991). The relatively few number of interactions seeking rationale or explanation indicates teams do not have sufficient understanding of the project issues or generally do not question the rationale or criteria for designs or schedules.

Structuring. Teams spent little time discussing project or process strategies or rules. Teams spent 6% to 18% ($\bar{x}$ =10%, σ = .04) of the time "structuring". Teams rarely state goals, strategies, or rules for the meeting or meeting tasks. Only three meetings in the analyses had any communication that explicitly stated

a meeting or process "goal". More common were the interactions that communicated strategies for accomplishing a goal and giving direction.

Relating. Keyword counts and keyword maps describe the differences in relating. Initiating rates ranged from 1.68 initiations per minute to 3.41 initiations per minute (Table 4-13). The 3.41 initiations per minute, though, had a disproportional number of initiate events to response events. This meeting was a design review and the team raised a number of issues without responding to many of those issues. The response rates ranged from 1.32 responses per minute to 2.22 responses per minute. The initiations per response rates ranged from 1.17 to 2.46 initiations per response, i.e., it takes several initiations to illicit a response or no response is given. There is one outlier, Meeting 10, which had a disproportionate number of initiations per response (2.46). Olson et al. (1992) reported in their review of design collaboration a median of 10 issues per meeting and a range of 1 to 44 issues per meeting. The findings here are similar. The number of new issues per meeting ranged from 5 to 61. The meetings examined here include design review and schedule review during which the identification and resolution of issues is a primary focus.

Table 4-13: Comparison of rates for initiating, responding, and initiating new issues. Shaded grey boxes are maximum values and dark shaded-grey boxes with white lettering are minimum values.

Meeting	Initiate	Respond	Initiate Rate (initiate/ minute)	Initiate/ Response	Response Rate (response/ minute)	Initiate New Issue	Issue Rate (issue/min ute)	Initiate/ Issue	Response/ Issue
Mtng 01	56	48	1.75	**1.17**	1.50	7	0.22	8.0	6.9
Mtng 10	140	57	**3.41**	**2.46**	1.39	**5**	**0.12**	**28.0**	**11.4**
Mtng 20	69	47	1.86	1.47	1.27	13	0.35	5.3	3.6
Mtng 30	178	141	2.62	1.26	2.07	19	0.28	9.4	7.4
Mtng 50	**267**	**227**	2.59	1.18	2.20	**61**	0.59	**4.4**	**3.7**
Mtng 60	**52**	**41**	**1.68**	1.27	**1.32**	7	0.23	7.4	5.9
Mtng 70	179	139	2.86	1.29	**2.22**	32	0.51	5.6	4.3
Mtng 80	249	189	2.28	1.32	1.73	43	0.39	5.8	4.4
Mtng 90	177	128	2.85	1.38	2.06	35	0.56	5.1	3.7
Average	152	113	2.44	1.4	1.75	25	0.36	8.77	5.70
σ	80	48	2.51	0.4	1.78	27	0.38	8.85	5.57

Keyword maps show greater differences in the pace and rhythm of the meetings and the relational process. Figure 4-6 shows five keyword maps for portions of five meetings. Note how these maps show distinct differences in the meeting activity. Some meetings go through repeated, rapid periods of a regular process of initiating, continuing, and responding (Figures 4-6[A] and [B]). Others have less structure and prolonged periods of communication or no communication. Also, note that the relational patterns recur several times in the meeting. These differences are more meaningful than the proportional analyses as they describe differences in how teams interact that the proportional analyses do not sufficiently capture.

I used the keyword maps to identify relational patterns. These keyword maps show four distinct relational patterns.

(A) ***Rapid initiate response pattern.*** These interactions involve a series of questions and answers that occur over a short time period. Typically, these interactions involve meeting participants who are knowledgeable and respond adequately to questions.

(B) ***Prolonged continuation.*** These are periods when someone initiates a new topic or issue and the subsequent interactions elaborate the issue without responding or resolving it.

Excerpt 4-14: Example of a prolonged continuation.

M115: The only concern we have with this is that we haven't run into lots of problems with the city in terms of footprint. They typically like to always have all the new brick on site. So the idea would come in the back like that. Stuff like that. So that might be a potential. So we talked about...	initiation
M116: Engineering kind of looks at it from project by project basis based on our chips as a result of where the building is requested and placed based upon (....)	continue
B117: with their parameters.	continue
M118: Exactly. So, ...if they have an issue with this or track even, they may umm agree to have moving happen on the street and have 2 parking spaces. Essentially what we've done is recognize the fact that all 4, 3 phases on the building are the same axis. The first thing we did is there needs to be a 3 meter zone around the building face that you can drive a lift or truck or something to it and treat it in a way that it could be done 365 days a year. So we thought this 3 meter zone umm right up against the building to keep really clean. We're proposing that there's some sort of river rock or decorative stone that you can drive on that and then reinforce or reinforce the …. area so you can drive on as well.	continue

(C) ***Confusion.*** These are periods when no initiation or response events occur and the team is communicating and typically culminate in someone explicitly stating confusion or frustration with the response.

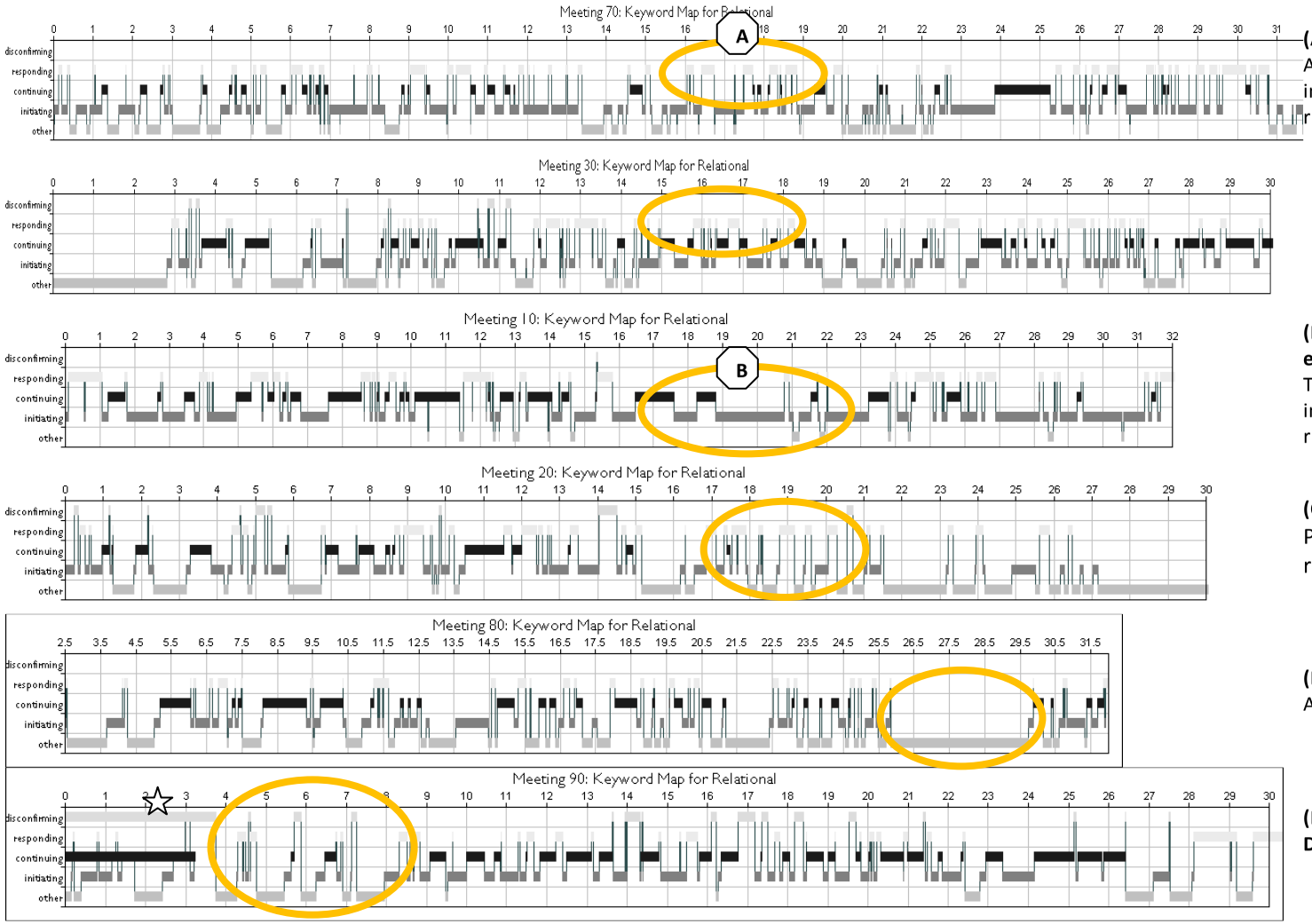
Excerpt 4-15: Example of a pattern of confusion.

M188: Sorry, I didn't make enough copies. I didn't know how many to go for. Umm...the first page is some visualizations leading through possible options with respect to the green roof as far as visibility from the street level and also umm on each page we've also presented images and also quotes from the public survey that might be helpful for people to keep in mind.	communication
M189: The second page ummm	communication
……	
M196: Ummm…the second page shows possible um, just a different perspective on how the green roof could be run to the ground level and also in that main picture in the middle we implemented some wood elements on the exterior to make that visible to the public.	communication
Y197: *((looking at paper))*	other
W198: Is there a trellis thing?	initiation
M199: Yeah, exactly, something that could be just columns a trellis or something like that has vegetation growing up on that as well.	response
D200: Where is this going?	initiation

(D) ***Repeated disconfirmation.*** These patterns involve a series of initiations without sufficient response or explicit disconfirmation. These patterns often occurred in review and status meetings when no one at the meeting had sufficient information to answer the questions or the person in the meeting could not commit to an answer.

Excerpt 4-16: Examples of disconfirmations or initiations followed by statements that do not adequately respond to the question.

G041: You're going to be done doing whatever the demo is...	initiation
B042: For sure by the end of this week. Hopefully earlier than that…	disconfirmation
BX048: That's all taken care of at the corridor? Are we shored up at that one wall?	continue
H049: Ye. I believe so. I haven't seen... I haven't looked at the revised coordination drawings but I did look at them yesterday.	disconfirmation



(A) Rapid initate-response
A pattern of initiation interactions followed by responses.

(B) Prolonged elaboration.
The elaboration of an initiation without a response.

(C) Confusion
Prolonged period of no response.

(E) No relating.
A period of digression.

(F) Initiating-Disconfirming

Figure 4-6: Keyword maps comparing different "relational" patterns of interaction.

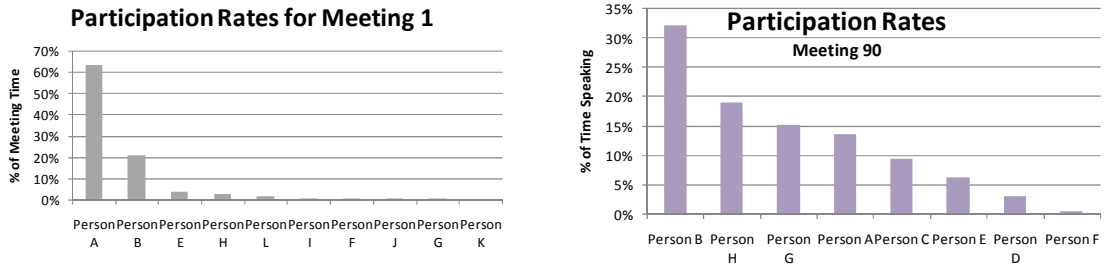
Expressing. Teams spent little time expressing positive or negative emotion, ranging from 1% to 9% ($\bar{x} = 4\%, \sigma = .02$) expressing positive or negative emotion. Since positive or negative expressions are short utterances, such as "That's great!" or "Good job!", I also compared counts and rates of positive and negative events (Table 4-14). This analysis shows the low number of negative interactions, particularly when compared to positive interactions. This compares with the findings in Gorse and Emmitt (2007). This tells us that compared to other events, any difference in positive or negative expressions are more significant as a portion of the observable events.

Conflicting. Conflict rarely occurs. Only three interactions exhibited conflict in two meetings (Table 4-14). When conflict occurs, though, it is noticeable.

Controlling and Dominating. All meetings had one meeting participant who spoke more than 30% of the time and almost twice as much as any other meeting participant. Although I excluded "controlling" from the analysis of moment-to-moment interaction, I used the transcript data to calculate the Gini coefficient for all meetings (see Appendix H). I include the data here as a reference point to show differences in participation across the meetings. The Gini coefficient values ranged from .41 to .74 ($\bar{x} = .58, \sigma = .09$) (Table 4-14). This gives some indication of meetings where one person controls or dominates the meeting, but all meetings had similar participation distribution curves of one person predominantly talking twice as much as any other participant (Figure 4-7). These distributions are similar to those reported in (Bales 1976).

Table 4-14: Comparison of negative and positive event counts and rates and participation rates. Only two meetings had any negative events with all meetings involving a relatively greater number of positive events.

	Conflict	Disagree	Agree	Positive	Agree Rate	Disagree Rate	Positive Rate	Time Spent Expressing	Gini Coefficient
Mtng 01	0	0	**10**	4	0.31	0.00	0.13	2%	0.74
Mtng 10	0	0	17	13	0.41	0.00	0.32	4%	0.60
Mtng 20	0	0	16	13	0.43	0.00	0.35	5%	0.62
Mtng 30	0	1	37	26	0.54	0.01	0.38	4%	0.62
Mtng 50	1	1	**87**	49	0.84	0.01	0.48	5%	0.64
Mtng 60	0	0	16	7	0.52	0.00	0.23	**1%**	0.53
Mtng 70	0	2	58	4	0.93	0.03	0.06	3%	0.52
Mtng 80	**2**	**8**	39	25	0.36	**0.07**	0.23	3%	0.50
Mtng 90	**0**	**5**	67	**79**	1.08	**0.08**	1.27	**9%**	0.41
Average	0	1.9	39	24	0.60	0.02	0.38	4%	0.58
σ	1	48	42	25	0.28	0.03	0.36	0.02	0.09



(A) Meeting 1: Gini Coefficient = .74 (B) Meeting 90: Gini Coefficient = .41

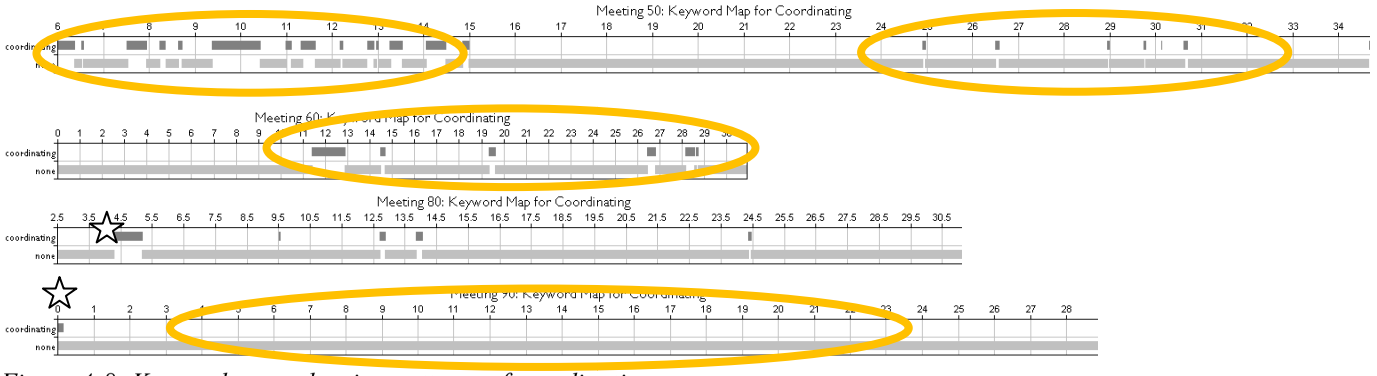
Figure 4-7: Comparison of distribution of participants in two meetings. (A) Shows participations rates for a meeting with Gini coefficient = .74 representing inequity or "dominance" and (B) meeting with more equal participation and a Gini coefficient = .41.

Doing. Teams spent 64% to 97% ($\bar{x} = 86\%, \sigma = .12$) doing project-artifact related activity (including time spent managing media). The two teams that spent less than 88% of the time "doing" were meetings during which the teams spent time learning to use media.

Coordinating. Teams spent from 4% to 16% ($\bar{x} = 10\%, \sigma = .06$) of the time "coordinating". Most meetings exhibited "ad hoc" coordinating patterns—infrequent and irregular timing of coordination events (Figure 4-8[B]). One meeting, for example, had only an initial coordinating event with little to no subsequent coordinating events (Figure 4-8[C]). Only one team had a structured coordinating pattern (Figure 4-8[A]), an initial set of meeting coordination activities followed by regular and intermittent periods throughout the meeting to coordinate.

Producing. Teams spent less than half the time making changes to the project artifact or meeting process. Even in conceptual design meetings, less than 40% of the time is devoted to the generation of ideas or alternatives. Teams spent from 1% to 37% ($\bar{x} = 10\%, \sigma = .12$) of their time producing and generating ideas or alternatives. The differences in producing are primarily attributed to the different meeting purposes. Meeting 60 was a conceptual design meeting, so this explains the significant amount of time spent "generating". The meeting with the lowest percent of time spent "generating" was a schedule review meeting.

Acting. Teams spent 48% to 92% ($\bar{x} = 69\%, \sigma = .15$) of the time working towards resolution of project issues, addressing issues initiated by meeting participants, generating project information, e.g., ideas or alternatives, or in closed-loop communication. Acting is one of the key differences in the Case Examples. Figure 4-9 compares keyword maps for the four Case Examples. These keyword maps show differences in the examples in "producing" and "acting". Meeting interactions A and C are examples of interactions that did not lead to any resolution or adequate response whereas meeting interactions B and D are "acting".



(A) Structured Coordinating
Initial set of "coordination" events involving multiple participants.

(B) Ad hoc coordinating
There is no regularity or structure to the coordinating activities. They occur infrequently and with no regularity.

(C) No coordinating

Figure 4-8: Keyword maps showing patterns of coordinating.

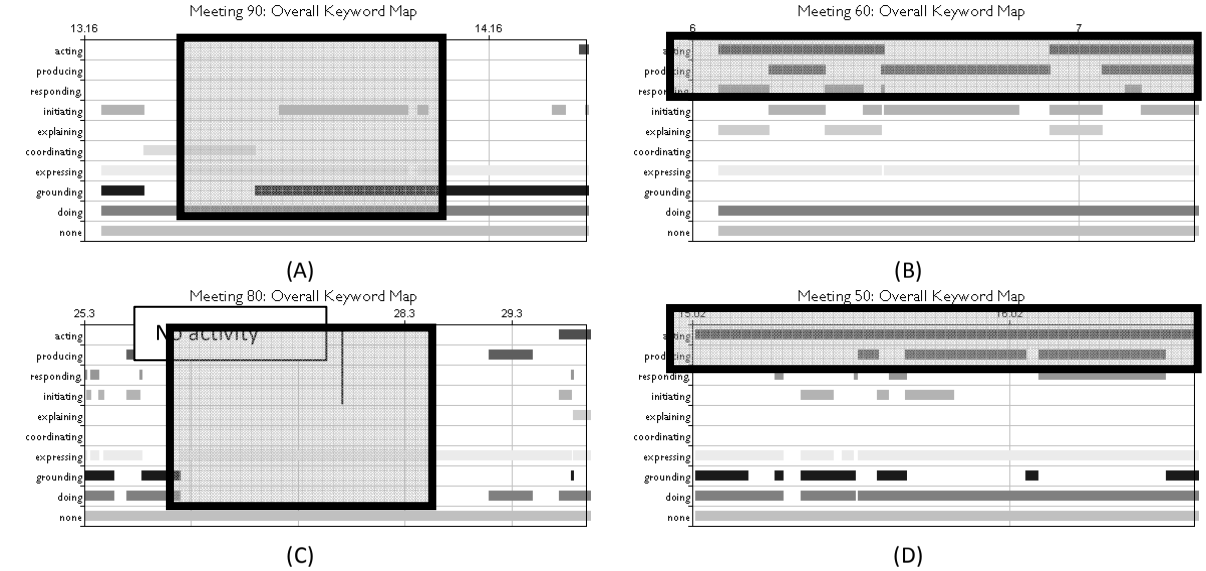


Figure 4-9: Comparison of team interaction behaviors for the four Case Examples in Chapter 1. This shows that Examples (A) and (C) spent no time "acting" or "producing" and Teams B and D spent a majority of the time "producing" and "acting".

4.6 Differences and Similarities in Media Use

Media use varies more significantly than team interaction. The average range of media use process measures was 54.6 % (Table 4-15) compared to 27.3% for the team interaction process measures, i.e., meetings differed more significantly in how teams used media than how teams interacted. Table 4-15 lists the proportional distributions.

Table 4-15: Comparison of time spent for all meetings by media use process.

			% of Meeting Time Team Spends…				
Level of Analysis	Media Use Process	Sub Process	Average $\bar{x}$	Standard Deviation σ	Minimum	Maximum	Range
Project	Use	Performing	18.6%	0.19	0.0%	55.1%	55.1%
	Purpose	Acting	18.4%	0.14	5.0%	49.8%	44.8%
	Interactivity	Working (Changing and Annotating)	16.8%	0.21	0.0%	58.1%	58.1%
	Purpose	Grounding	45.1%	0.24	15.6%	80.1%	64.5%
	Use	Sharing	59.2%	0.39	0.0%	98.5%	98.5%
Process	Use	Transitioning	13.3%	0.20	0.5%	66.1%	65.6%
	Purpose	Coordinating	6.6%	0.06	0.9%	20.9%	20.0%
	Use	Integrating	9.3%	0.15	0.0%	38.7%	38.7%
Interpersonal Interaction	Interactivity	Directing (Pointing)	12.7%	0.09	2.1%	25.7%	23.6%
	Use	Learning					
	Use	Supporting	51.9%	0.20	22.9%	78.8%	55.9%
	Use	Utilizing	70.5%	0.28	23.0%	98.5%	75.5%
							$\bar{x} = 54.6\%$

Using. The meetings represent a range of media use by type, modality, and utilization. Teams spent 23% to 99% of the time ($\bar{x}$=71%, σ = .28) using media. One team used only digital media, three teams used only paper media, and five teams used paper and digital media (Figure 4-10). The mode of communication ranged from periods of verbal communication, to verbal plus media ("supporting"), to media as the primary source of communication ("performing") (Figure 4-11). There was a wide range of time spent "supporting" from 16% to 82% ($\bar{x}$=52%, σ = .23); as a percentage of media use, "supporting" ranged from 42% to 84% ($\bar{x}$=52%, σ = .23). Similarly, "performing" ranged from 0% to 55% ($\bar{x}$=19%, σ = .19).

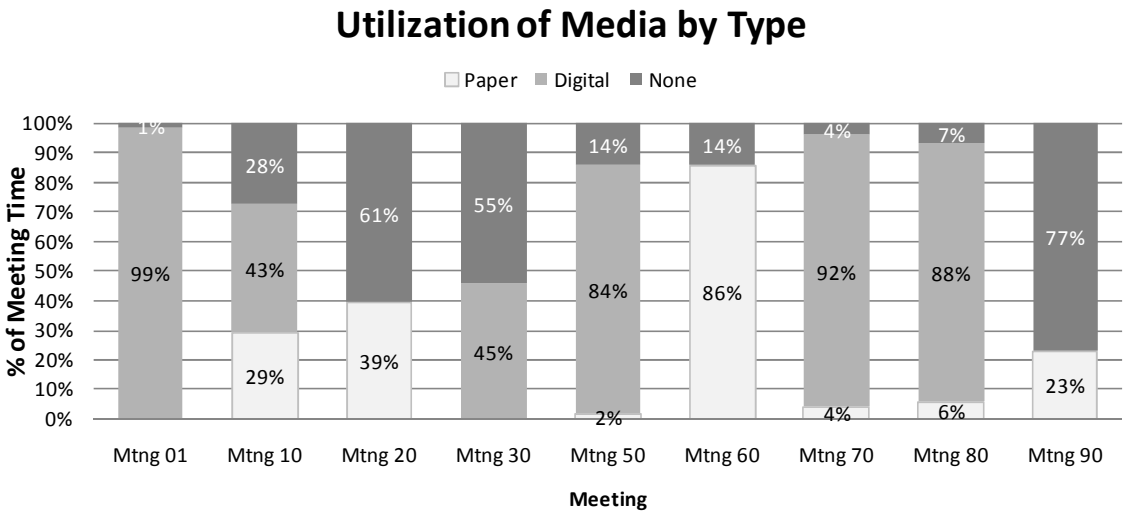


Figure 4-10: Chart comparing percent of time spent using digital or paper media. The meetings ranged from little to no use of any media (Meeting 90) to meetings using paper media predominantly (Meeting 60) and digital media predominantly (Meeting 1). The mixed-media meetings (Meetings 10, 70, and 80) used digital media predominantly.

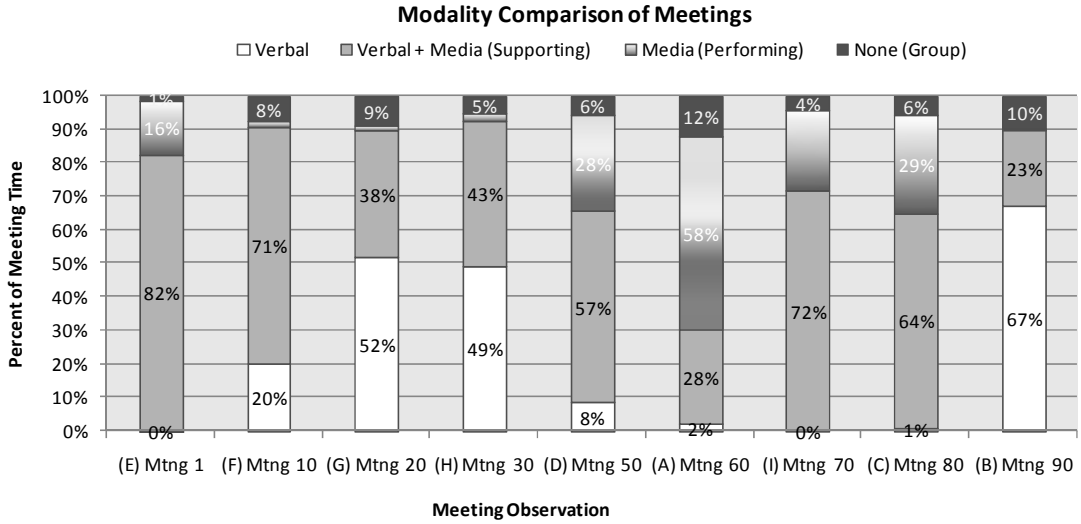


Figure 4-11: Chart comparing media modality in the nine meetings. The chart compares time spent communicating: verbally, verbally plus using media, and only using media.

Accessing. Access did not vary within meetings considerably or between meetings with similar media environments. Teams used shared media 0% to 99% ($\bar{x}$=59.5%, σ = .39) of the meeting. Seven meetings used shared media for more than 94% of total media use time (Figure 4-12). One meeting, Meeting 10, used semi-shared media for 41% of the time, and one team predominantly used private and single media. The patterns of access, though, tell more about how teams move between different media. Figure 4-13 shows three "accessing" patterns. The first is a "dividing" pattern where teams use media that are semi-shared with no media sharing. These interactions typically act as dividers and separate the meeting into groups depending on the location of the media. The second is a "mixed access" pattern where teams move between sharing and semi-sharing media. These patterns are typically associated with switches in focus

from a public display to media on a table or other display that are not accessible to the team. The third is a "private" pattern of media use during which a team member refers to a document as a source of information, and the team members focus attention on the document as opposed to one another.

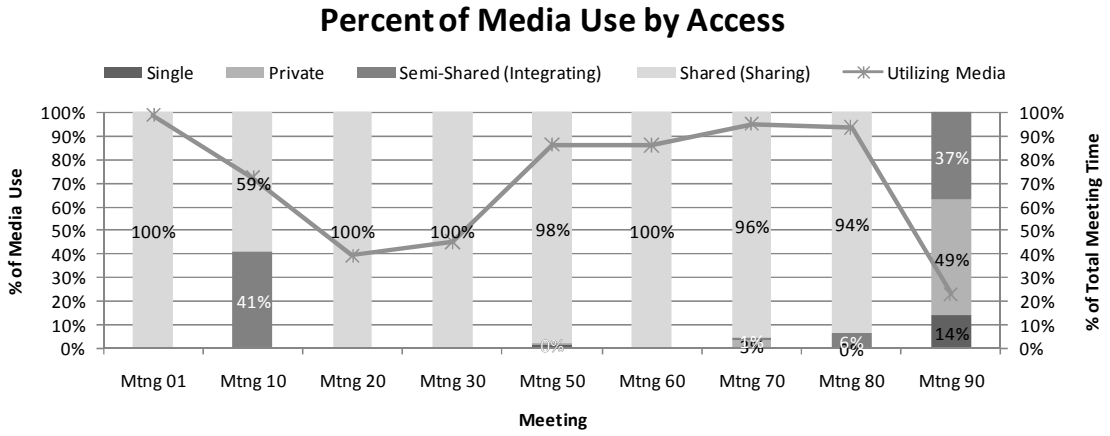
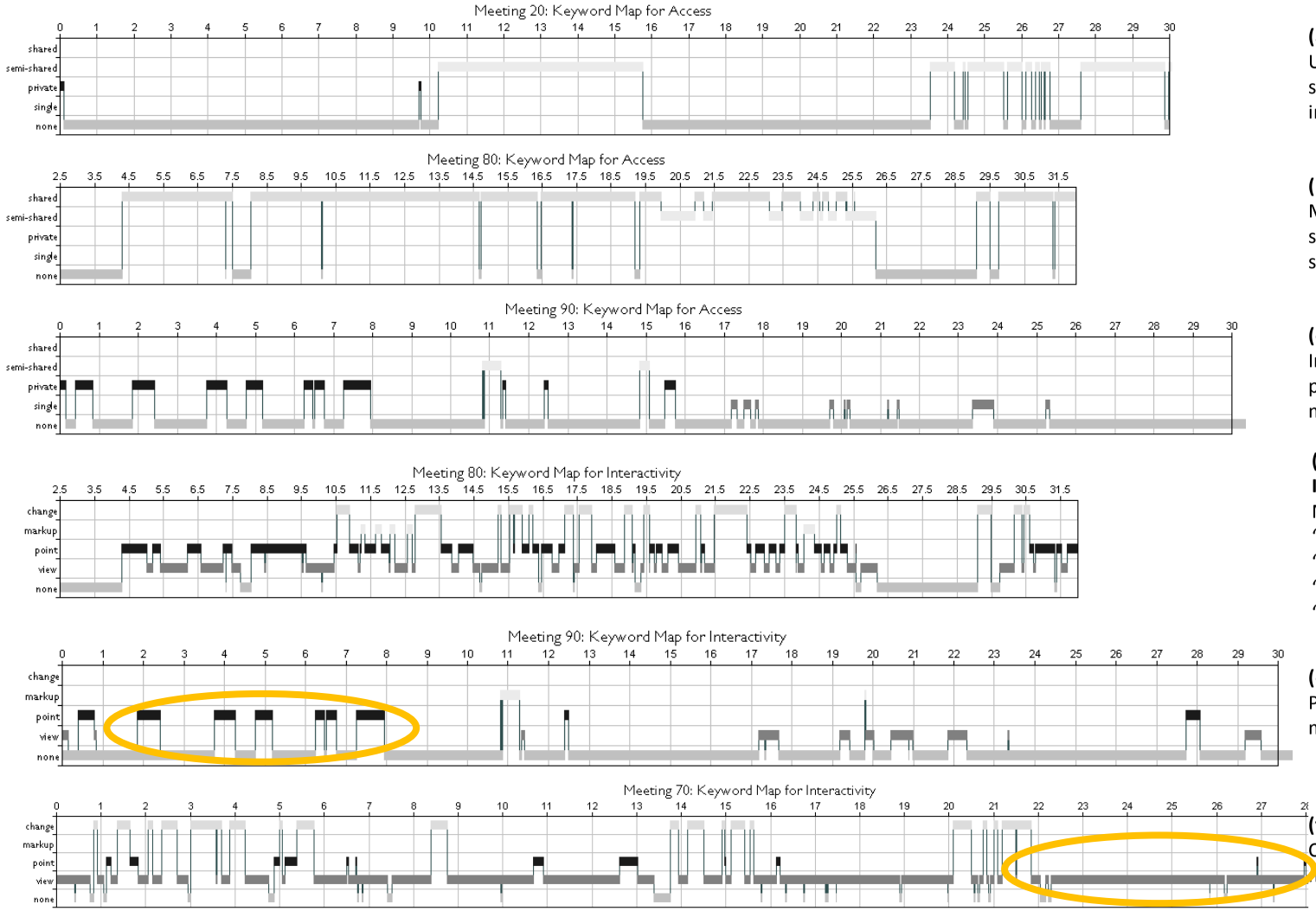


Figure 4-12: Comparison of time spent using shared, semi-shared, private or single media as a percentage of time utilizing media. The line shows the percentage of time the team used any media in the meeting.

Table 4-16: Comparison of transition rates for the nine meetings.

Meeting Number	Access Transitions	Media Transitions	Interactions	Time	Access Transitions/ Interaction	Media Transitions/ Interaction	Access Transitions/ Minute	Media Transitions/ Minute
1	8	5	188	32	0.04	0.03	0.25	0.16
10	24	21	223	41	0.11	0.09	0.59	0.51
20	19	19	294	37	0.06	0.06	0.51	0.51
30	28	22	567	68	0.05	0.04	0.41	0.32
50	85	82	1070	103	0.08	0.08	0.83	0.80
60	18	3	155	31	0.12	0.02	0.58	0.10
70	74	3	607	62.5	0.12	0.00	1.18	0.05
80	52	41	859	109	0.06	0.05	0.48	0.38
90	48	4	726	62	0.07	0.01	0.77	0.06
Average	39.6	22.2	521.0	60.6	0.08	0.04	0.62	0.32
σ	26.8	25.8	326.4	29.2	0.03	0.03	0.27	0.25
Min	8	3	155	31	0.04	0.00	0.25	0.05
Max	85	82	1070	109	0.12	0.09	1.18	0.80
Range	77	79	915	78	0.08	0.09	0.93	0.75

Teams varied in the number and rate of transitions between media and media access. The transition analysis examines two types of transitions. The first are transitions between different types of media. These include transitions from a drawing on a display to a model as well as transitions from a schedule on a table to a drawing on the table. Teams averaged 22.2 media transitions per meeting and .32 transitions per minute (Table 4-16). The second are transitions in access, e.g., from shared to semi-shared media. Teams averaged 39.6 transitions per meeting and .62 transitions per minute (Table 4-16). Figure 4-15 shows three patterns of transitions. Note how these patterns recur every few minutes and do not change dramatically within one meeting.



(a) Limited access
Use of private and semi-shared media intermittently.

(b) Mixed access
Moving between shared and semi-shared media.

(c) Private access
Infrequent use of private and single media.

(d) Dynamic Interactivity
Moving between "viewing," "pointing," "annotating," and "changing."

(e) Directing
Periodic pointing to media.

(f) Passive
Constant "viewing" of media.

Figure 4-13: Keyword maps showing moment-to-moment changes in "access" and "interactivity".

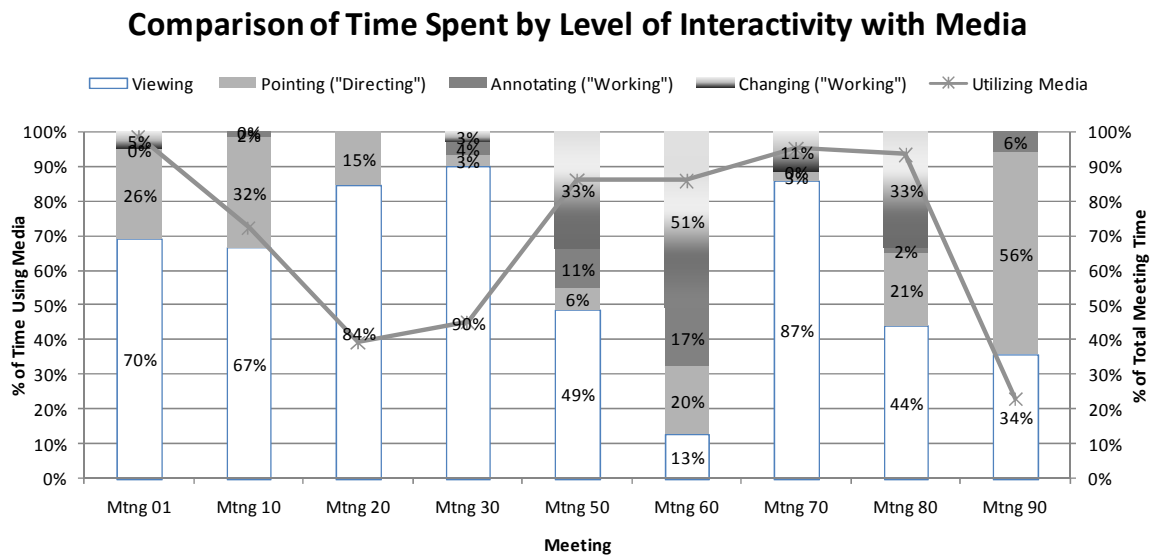


Figure 4-14: Comparison of time spent interacting with media. The predominant amount of time is spent viewing media with three meetings spending more than 30% of the time changing media.

Interactivity. The level of interactivity with media varied significantly across the meetings (Figure 4-14). Most of the time the teams spent viewing the media, ranging from 13% to 90% of meeting time ($\bar{x}$=60%, σ = .26). Next, was time spent "pointing" ("directing"), 3% to 256% ($\bar{x}$=20%, σ = .17), then "changing", 0% to 51% ($\bar{x}$=15%, σ = .19), and annotating, 0% to 17% ($\bar{x}$=5%, σ = .06). Figure 4-13 shows three patterns of interactivity. The first, Figure 4-13[d], is a dynamic pattern of interactivity showing a team moving between viewing, pointing, annotating, and changing periodically. The second, Figure 4-13[e], is a "directing" pattern of interactivity involving pointing to private media. The third, Figure 4-13[f], is a passive pattern involving only viewing.

Purposing. Teams spent most of the time using media to "communicate", ranging from 40% to 81% ($\bar{x}$=63%, σ = .16). Two meetings spent 44% and 68% of the time "learning" and one team spent a majority of the time, 58%, using media to "produce" project information. All the meetings spent some time using media to coordinate, ranging from 2% to 21% of the time ($\bar{x}$=8%, σ = .06).

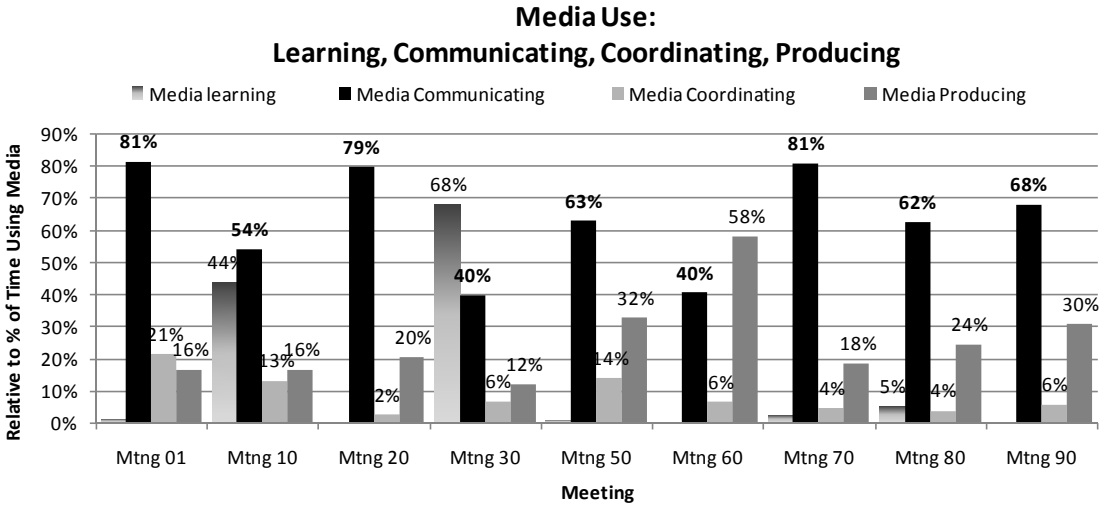


Figure 4-15: Comparison of time spent by instrumental purpose of media. Most teams use media to "ground"("describe", "explain", or "communicate").

4.7 Patterns of Mediated Interaction

These analyses demonstrate the use of the Mediated Interaction Analytic scheme to interpret a range of team interaction and media use and describe, independently, the differences in how teams interact and how teams use media. What, if any, patterns of team interaction, media use, or mediated interaction are discernable from these results? Do any behaviors relate to one another, that is, is more time spent "explaining" associated with more time spent "acting"? What is typical or atypical interaction? I performed a variety of analyses to answer these questions:

- ***Correlation analysis*** (see Appendix M). Like Olson et al. (1992), the correlation analysis did not identify any significant correlations between any of the team interaction process measures. The correlation analysis showed positive correlations between similar constructs and negative correlations between dissimilar constructs (convergent and divergent validity checks).
- ***Frequency and variability analyses***. Table 4-15 lists the interaction behaviors by frequency of observation and variability. Typical interaction is "exchanging", "doing", and "acting" and atypical is "expressing" and "structuring". Typical media use is "utilizing," "sharing", and "supporting", and atypical media use is using media to coordinate or using "semi-shared" media. The results also show that the type of media or frequency of use does not explain differences in how teams interact.
- ***Keyword maps*** combining all process perspectives (Figure 4-9). The maps show patterns for a single analytic category with two to six categorical distinctions, but are difficult to interpret for interactions spanning more than two or three minutes or with multiple categorical distinctions.
- ***Team interaction profiles*** and ***media use profiles*** combining analysis of time spent for each of the team interaction and media use processes respectively (Figure 4-16[A] and [B] and Figures N-1 and N-2). These show that meetings are more similar than different, and team interaction differs more at the

"project" level, i.e., with respect to acting on project issues and producing alternatives. The profiles, though, do not communicate the temporal aspect of the interaction.

- ***Mediated interaction profiles*** (Figure 4-16[C] and Figure N-3 comparing all interaction process measures. Since some of the proportional analysis numbers are low, I normalize each MIM construct using the maximum value from all nine meetings. For example, the maximum "grounding" value is 70% for Meeting 1. The grounding values for Meeting 70 normalizes from 62% to 88%. Appendix N includes MIA radar charts for the nine meetings. The charts show that two meetings, Meetings 50 and 60, have relatively higher proportions of more than half the MIM constructs. Conversely, Meetings 30 and 90 have smaller "profiles".

Table 4-17: Comparison of interaction processes ordered by frequency and variability. This shows that there is more variability in the media use processes than in the team interaction processes. Shaded process measures are team interaction process measures.

Ordered by Frequency of Observing Behavior Relative % of Time	
Doing /Exchanging	85.7%
Utilizing	70.5%
Acting	69.7%
Sharing	59.2%
Supporting	51.9%
Grounding	49.6%
Communicating	45.1%
Initiating	29.5%
Viewing	41.6%
Responding	28.6%
Performing	18.6%
Media Producing	18.4%
Changing	16.8%
Transitioning	13.3%
Directing (Pointing)	12.7%
Explaining	10.4%
Producing	10.3%
Coordinating	10.2%
Integrating	9.3%
Structuring	9.2%
Learning	7.6%.
Media Coordinating	6.6%
Expressing	4.4%

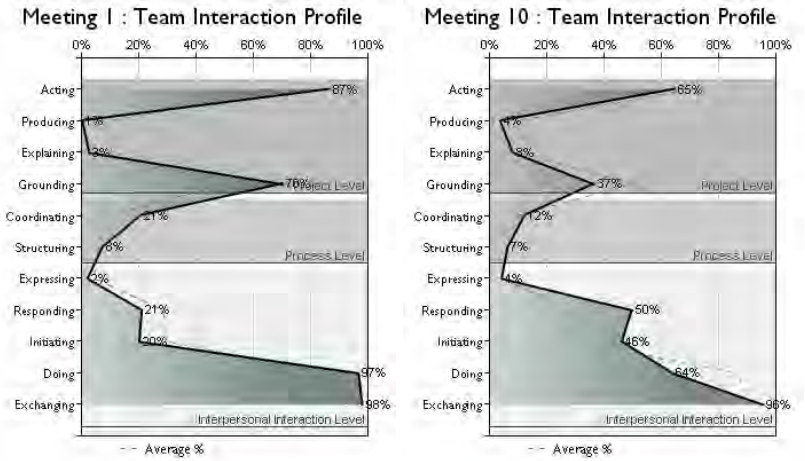
Ordered by Variability of Observing Behavior Standard of Deviation	
Sharing	0.39
Utilizing	0.28
Communicating	0.24
Viewing	0.24
Changing	0.21
Transitioning	0.20
Supporting	0.20
Performing	0.19
Acting	0.15
Responding	0.15
Integrating	0.15
Media Producing	0.14
Learning	0.13
Grounding	0.13
Doing /Exchanging	0.12
Producing	0.12
Initiating	0.09
Directing (Pointing)	0.09
Media Coordinating	0.06
Coordinating	0.06
Explaining	0.05
Structuring	0.04
Expressing	0.02

The MIA analyses tell *what* happened in the project meetings, but not *how*, in a meaningful or coherent way. The results show differences in all aspects of team interaction and media use, but no significant difference or correlation between team interaction behaviors and media use. These findings support the notion that the relationship between team interaction and media use is complex and no single aspect of team interaction or media use explains differences in meeting interaction. Based on these findings and analyses, there is a need for a method to better describe and compare meeting interaction process using temporal and categorical data. There is also a need for process constructs that combine the different aspects of team interaction and media use. The following chapters address these shortcomings of the current approaches using the findings from the MIA analysis and further operationalize the MIM concepts.

4.8 Summary

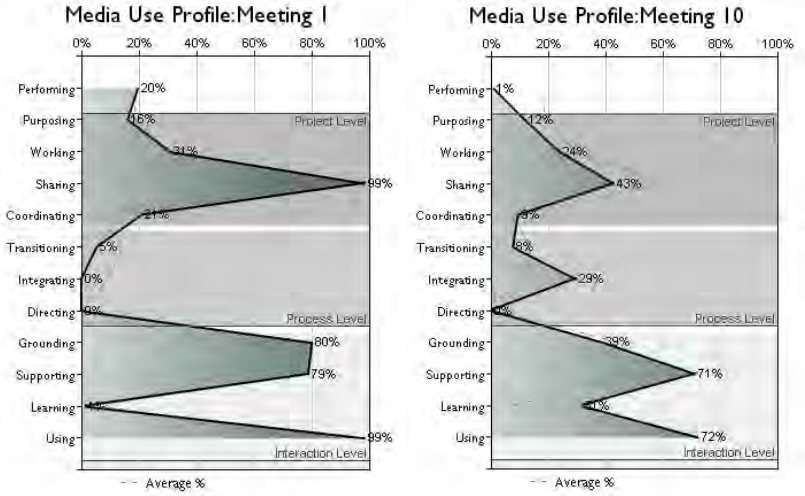
This chapter elaborated the concepts in MIM and developed an analytic scheme to interpret and describe differences in team interaction and media use. I provided evidence for the reliability of the scheme, and all coding categories met high intercoder reliability standards. As evidence for the power and generality of the scheme (to AEC multi-disciplinary project meetings) I applied it to nine AEC project meetings to describe differences in the meeting interaction with respect to these processes. The MIA coding scheme applies to a wide range of meetings varying in the nature of the activity and use of media.

More challenging is demonstrating that the MIA scheme and analyses measure what I intend them to measure (construct validity). MIA reflects my conceptualization of project meetings, the goal in this chapter is providing evidence for the rationale and selection of the seven coding schemes in relation to MIM processes. The literature review (Chapter 2) and comparative analysis in this chapter offer evidence for the selection of the concepts examined and analyzed in the MIA scheme. Since my conceptualization of interaction excludes tasks or features of media, the MIM ontology and scheme does not specify codes for tasks or media features—two aspects that researchers commonly examine. This does not mean that differences in tasks or different media features do not exist, but that my view of the relationship between team interaction and media use does not examine these aspects. I intentionally excluded examining specific tasks because the focus here on how they interact as they perform tasks and achieve goals. This makes it possible, then, to compare different meeting interactions independent of the nature of the task. MIM makes the assumption that regardless of the task, it is possible to compare team interaction and identify characteristics of team interaction that are associated with positive outcomes with respect to the project, meeting process, and the interpersonal interactions associated with a task.



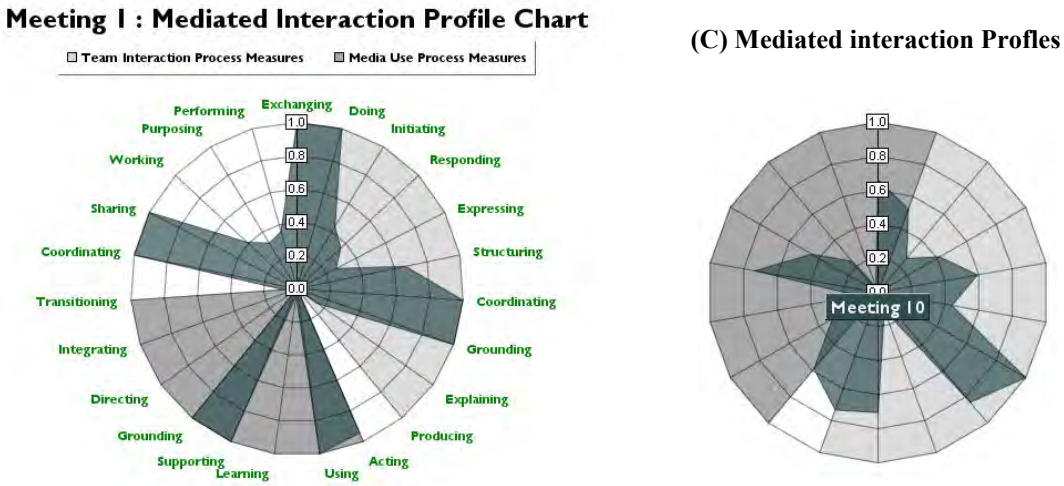
(A) Team Interaction Profiles

The team interaction profiles (see Figure N-1) do not communicate significant differences in team interaction process measures. The profiles follow a similar profile (dashed line). There are more differences at the project-level.



(B) Media Use Profiles

The media use profiles (see Figure N-2) show more differences in media use at all levels of analysis.



(C) Mediated interaction Profles

Figure 4-16: Examples of different visualization methods to describe and compare differences in team interaction and media use. The (A) Team Interaction and (B) Media Use profiles compare the time teams spent in relation to the MIM processes. (C) The Mediated Interaction profile chart combines all MIM processes. I include these profiles and charts to illustrate the shortcomings of existing visualization methods. These methods miss the temporal aspect of the interaction and do not adequately convey the relationships, if any, between team interaction processes and media use processes.

Chapter 5: Mediated Interaction Spectra

"In choosing, constructing, and comparing graphical methods we have little to go on but intuition, rule of thumb, and a kind of master-to-apprentice passing along of information.... there is neither theory nor systematic body of experiment as a guide."

(Kruskal 1975, p. 28-29 as cited in Cleveland and McGill 1984)

5.1 Introduction

Capturing and conveying the important nuances of natural interaction in a single construct, model, chart, or table is challenging. Operationalized constructs, models, and graphical methods abstract natural phenomena to text, numbers, measures, metrics, charts, and diagrams. Researchers select models and methods that reflect what is important to the research goals and that answer the research questions. Observational data that are multi-categorical and temporal pose several challenges for operationalizing constructs and selecting graphical methods. Multi-categorical constructs require the researcher to explain the rationale and assumptions in the operational definition. Existing graphical methods, as shown in the previous chapter, fail to describe the temporal aspects, behavioral nuances, and relationships between those nuances from multiple perspectives in a manner suitable for comparison. Before we can relate the processes of media use and team interaction we must first describe those processes independently. This chapter addresses this issue by posing and answering the following research question:

(RQ3a) How can the process of team interaction be operationalized and visualized to describe and compare team interaction relative to the range of team interaction observed in AEC project meetings?

(RQ3a) How can the process of media use be operationalized and visualized using MIM and MIA to describe and compare team interaction relative to the range of media use observed in AEC project meetings?

I answer this question in three parts. First, I identify the features of visualizations that are sufficient to convey and discover differences in observed behavior over time. Second, I discuss the conceptualization and operationalization of two multi-dimensional constructs as a spectrum of interaction to describe team interaction and media use

1. ***Richness of Interaction*** comprises three "zones" of interaction to represent the range of interaction from breakdowns to synergies.
2. ***Richness of Media Use*** to represent the range of media use from no use to rich media use.

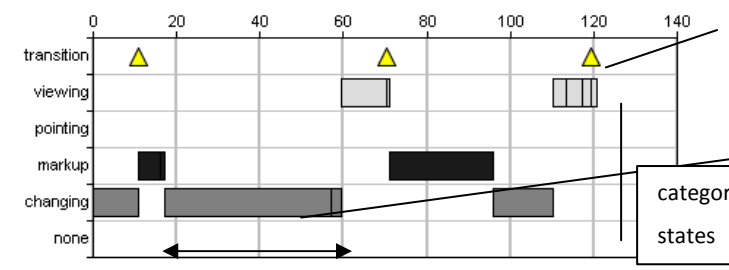
These multi-categorical and temporal constructs act as standards to describe and compare each meeting interaction based on the observational data presented in Chapter 4. Finally, I generate spectra visualizations that describe the process of team interaction and media use. I use these visualizations to illustrate patterns of team interaction and media use. They show that teams establish patterns of team interaction early in meetings and rarely deviate from those patterns.

5.2 Visually Describing Behavior

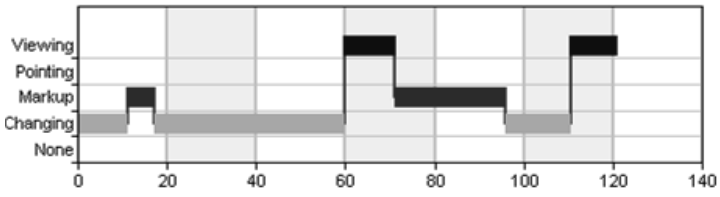
Interaction analysis methods produce data that are temporal, event-based, and categorical. Graphical methods supported by tools typically rely on quantitative or relational data and do not readily support event-based data. Interaction analysis researchers typically use the methods discussed in the previous chapter, presenting data using either 1) proportional analysis while removing temporal aspects or 2) keyword maps that capture the events but do not support comparison or communicate relationships between categorical perspectives. The researcher has to be careful in the selection of the visualization method and presentation of the data to ensure that the method reflects the relationships and abstraction of the phenomena that fit the research focus. The researcher must pay attention to the many features and elements of visualizations that act as guides for interpretation, such as axis, labels, colors, and bands. Each element acts as a guide to interpret a dimension of the behavior: temporal, relational, categorical, numerical, and so on (Cleveland and McGill 1984). These elements relate to the perceptual and cognitive tasks that one performs while interpreting charts and diagrams. The following sections discuss the elements of visualizations that are necessary to visualize multi-categorical, temporal-based behavior.

Occurrences and events. Researchers abstract behaviors as occurrences or events. Occurrences are "counts" and represent when an occurrence occurs. In a chart, occurrences are single data points, plotted in relation to a temporal value, for example, a start or end time. For example, Figure 5-1(A) visualizes the occurrence of a transition between media. Events represent when and how long a behavior occurs. Event-based visualizations graphically represent the start time, duration, and end time for an event. Event-based visualizations also convey changes in behavioral states or the categorical changes in behavior. Keyword maps, for example, are event-based (Figure 5-1[A]) and convey the temporal aspects and state changes. Keyword maps include three visual features: changes in behavior through categorical events, duration of those events, and relating those to a timeline. Figure 5-1(A), for example, shows a keyword map for one focus of analysis distinguishing four behavior states. Simple states are "on/off", that is, the behavior occurs or does not occur. For example, the team is using media or not using media. The bar lengths convey the temporal dimension of the meeting dynamics, and the location of the bar in different rows conveys the transitions and changes in behavior states. Sometimes a combination of both approaches is necessary since it is best to analyze some behaviors as counts and others as events. For example, Gantt charts are event-based visualizations that convey changes in behavioral states as activities and describe occurrences as milestones.

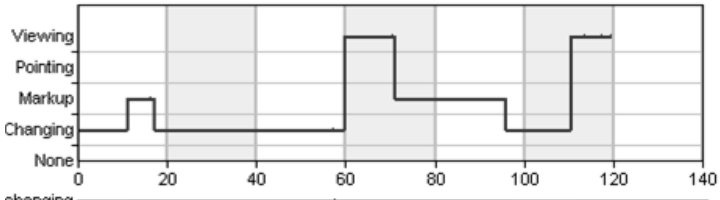
State transitions. Visualizing multi-state changes is complex for natural behavior. The challenge for observational data is whether the researcher wants to convey a relationship between states and how to communicate that relationship. The keyword maps intentionally do not show relationships between categories. The temporal transitions and relationships are implicit in keyword maps, making it difficult to interpret or "follow" changes in behavior. One can interpret transitions for a small number of categories and small set of events (Figure 5-1[A]), but it is difficult to do so for a large number of categories or a long sequence of events (Figure 5-3[A] and Figure 5-3[B]). One method to support interpretation of transitions



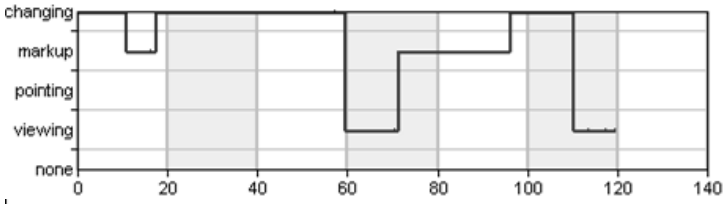
A) keyword map showing temporal changes in level of interactivity



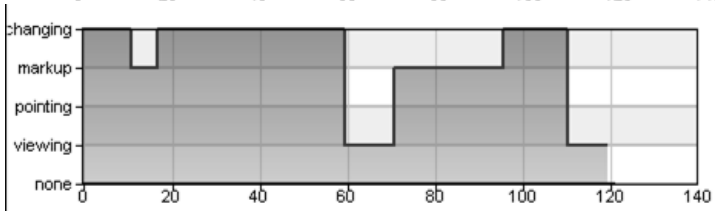
B) An unordered keyword map with vertical "links". The link lines make it easier to follow the behavioral transitions. Longer transitions may be interpreted as a "greater" difference in interaction.



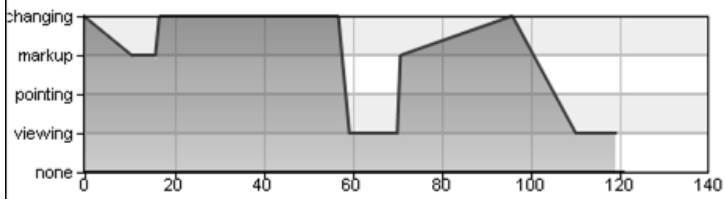
C) An unordered stepline. The vertical order of the categories implies order even though the categories are randomly ordered..



D) Ordered stepline with the 'high' interactivity placed at top and no interactivity at the bottom.



E) Gradient-filled stepline that shows how differences in y-values may be distinguished using color.



F) Gradient-filled "sparkline" that emphasize transitions from one behavioral state to another behavioral state.

G) Sparkline showing relative "interactivity" changes over time. Sparklines are small, embedded graphics that often strip the labels from the graphics to emphasize y-value and x-value changes (Tufte 2006)

Figure 5-1: Examples of various visualization methods to compare features of the displays that convey state changes, temporal duration of those states, time and transitions between states, and relative order or value between states. The progression of examples shows how different features emphasize different aspects of the categorical and temporal data.

is adding "links" between transitions (Figure 5-1[B]), a method common in Gantt Charts. Links act as a visual aid to follow the behavioral transitions. Removal of the event bars creates a Stepline chart (Figure 5-1[C]). Steplines are modified line charts that link "states" or data points and emphasize the transitions between states. Sparklines (Figure 5-1[H]) are "small, high-resolution graphics embedded in a context of words, numbers, images. Sparklines are data-intense, design-simple, word-sized graphics" (Tufte 2006, p. 7). Sparklines provide one way to simplify the task of representing a pattern of behavior.

Visual order and structure. The link lines act as guides for following the links upward and downwards: differences are interpreted as a function of the vertical distance between the categories or the length of the link line. For example, the transition link from "changing" to "markup" is shorter than the transition from "changing" to "viewing" (Figure 5-1[B]). The location of time labels also act as guides for interpreting the data from top to bottom (Figure 5-1[A]) or bottom to top (Figure 5-1[B]). These visualization features act as guides to interpret the visual data. There are three approaches to ordering categorical data: foci-ordered, process-based, and value-based. Foci-ordered approaches order categories relative to the foci of the research and relationships the research investigates. For example, Bales' IPA profiles use the foci-ordered approach (see Chapter 3) showing relationships between positive and negative expressions and the question and answer activities. Process-based approaches order categories relative to a standard workflow to show patterns that follow the standard process to those that do not follow the standard process. Value-based approaches order categories relative to a standard of performance. The approach here is value-based; Sections 5.3 and 5.4 elaborate this ordering approach.

Colors and Banding. Color or shading also plays a role in interpretation. Figures 5-1(A-D), for example, use vertical bands to distinguish the temporal aspect of the data, whereas Figures 5-1(E-G) use horizontal bands to distinguish the value or categorical aspects of the data. Banding acts as a guide to make distinctions between data values or groupings of data. Color can also highlight zones of values, such as the single band in Figure 5-1(G). These help the reader to interpret "zones" of behavior and when and how often observation of certain behaviors occur. They also help to distinguish the pattern of behavior and movement between zones of behavior. Here the emphasis is on using colors and banding to distinguish differences in categorical states and zones of behavior.

Scale. Visualization methods must take into account the quantity of data and unit of analysis. Tables and proportional analysis are appropriate for most studies since they abstract the data to single construct numbers regardless of the total amount of data, either in terms of categorical distinctions or temporal time scale. Visualizations that plot data in an X-Y chart, though, must establish scales for each axis. Employing a large number of categories, such as those in Figure 3-11(A), makes it difficult to interpret categorical distinctions. A large time scale, relative to unit of analysis, for example, hours to seconds, makes it difficult to interpret differences. For example, Figure 5-3 shows four different types of scales. The Keyword map in Figure 5-3(A) has ten categories for thirty-six minutes, making it difficult to interpret the patterns from a categorical perspective. Keyword maps, like Gantt charts, are difficult to interpret when the unit of analysis

is small relative to the level of analysis (Figure 5-3). Keyword maps are difficult to interpret as the number of categories increases (Figure 5-3[A]). The researcher must balance the scope of analysis with the foci of analysis. This is why it is often necessary to aggregate analytic categories or to make changes to the granularity of analysis.

Relationships. The examples in Figure 5-1 describe relationship between a single analytic perspective with four categorical states. Figure 5-2 illustrates the challenge of describing the relationship between analytic perspectives or between constructs using several categorical states. Figure 5-2 shows the changes in behavior from the media use perspective and interaction perspective. Figure 5-2(A) shows one approach that combines two perspectives, and Figure 5-2(B) overlays the two approaches. Both are difficult to interpret and show the challenge of describing relationships with multiple dimensions of analysis.

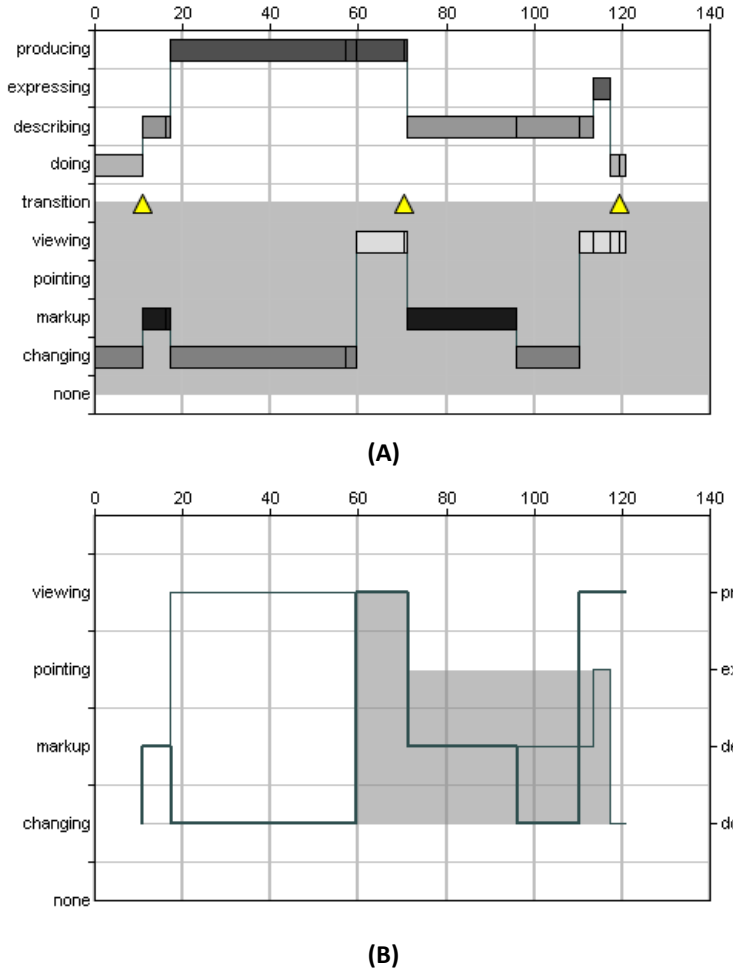
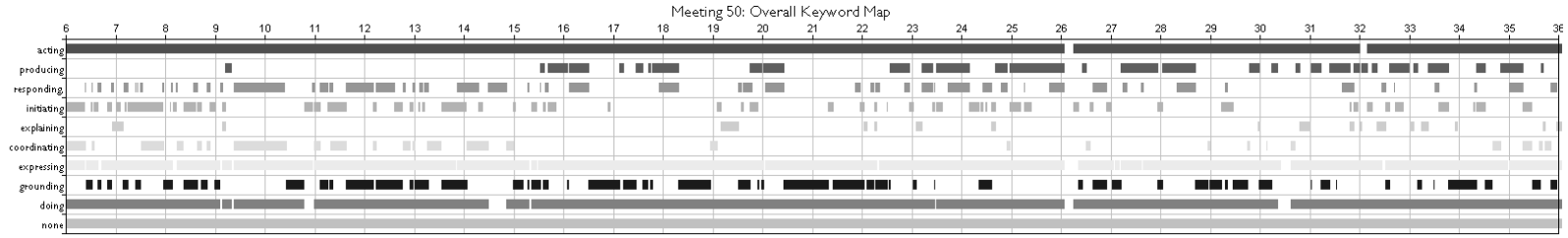
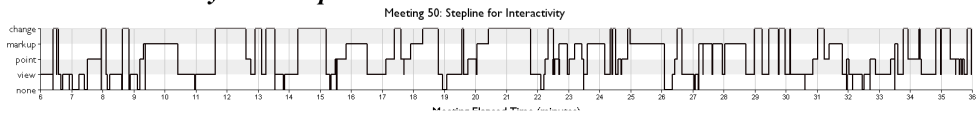


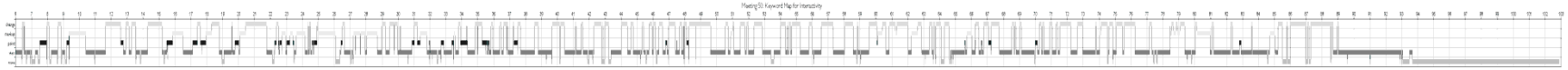
Figure 5-2: Examples of describing behavior from two analytic perspectives. (A) A combined approach. The shaded zone shows the categorical states related to interactivity and media use and the unshaded zone shows the categorical states related to interaction. The chart shows the challenge in describing the relationship between two analytic perspectives or two distinct analytic foci. (B) Overlay of behavioral perspectives.



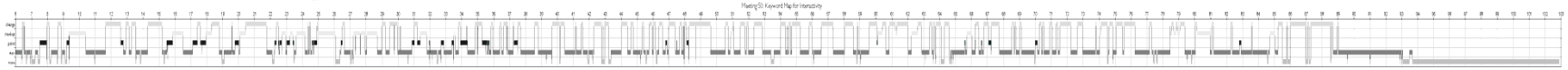
A. 30 minute Keyword Map



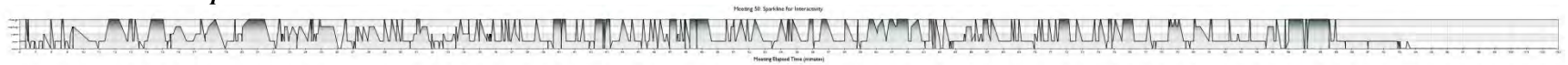
B. 30 minute Stepline



C. 90 minute Keyword Map



D. 90 minute Stepline



E. 90 minute Sparkline

Figure 5-3: Examples of Keyword Maps, Steplines, and Sparklines at different time scales, 30 minutes and 90 minutes. This shows the challenges in interpreting categorical data using (A) Keyword maps, (B) Stepline, and (E) Sparkline, when the level of granularity of analysis is small relative to the overall number of units and the number of categories of analysis. For example, for a 30-minute portion of the meeting, the unit of analysis is the interaction, that is typically a few seconds in duration, resulting in 5 to 12 units of analysis/minute.

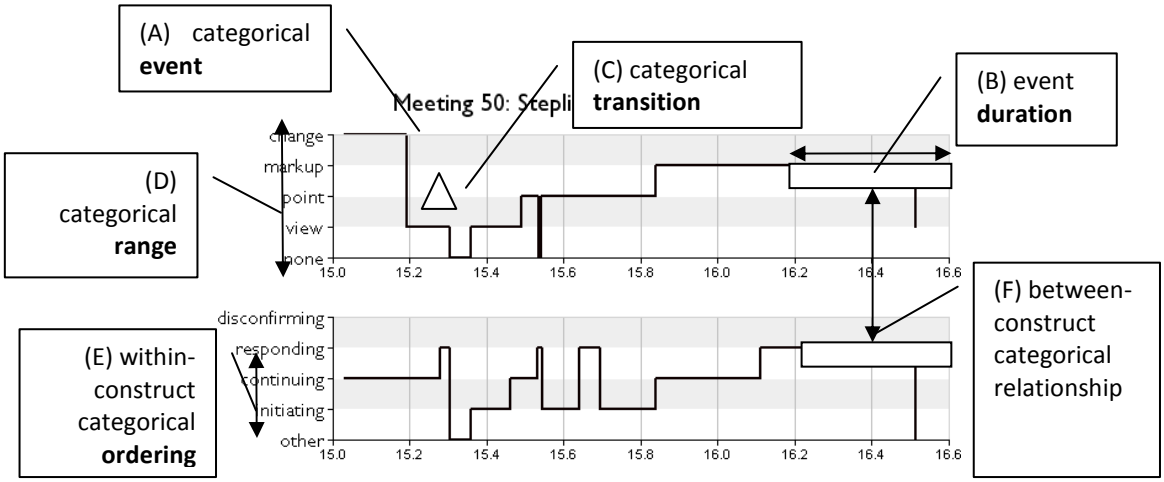


Figure 5-4: Summary of the visualization features to visually describe temporal, categorical behavior,r and categorical relationships. These features include: (A) event, (B) duration, (C) transition, (D) range, (E) within-construct relationships, and (F) between-construct relationships.

In summary, Steplines and Sparklines communicate three aspects of graphical methods necessary to visualize multi-categorical, temporal observation-based data:

a) Describe temporal aspects of behavior changes through x-axis ordering.

b) Describe behavioral state transitions through "links."

c) Describe relationships between categories through banding and y-axis ordering.

Generating these visualizations requires methods to aggregate and order categories for within- or between-construct analysis. The following section proposes a method to order and structure the data from a categorical perspective or "within-construct" analysis. These methods do not address the issues of scale or how to visualize relationships between two distinct analytic foci. Chapter 6 discusses an approach for visualizing "between-construct" relationships for an entire meeting process.

5.3 Visualizing Multiple Perspectives of Interaction

The Mediated Interaction model views interaction as multi-dimensional. I employed a variety of visualization methods, many of which were experimental, to convey the multi-categorical nature of interaction. One method is "layered" Steplines or Sparklines that visualize interaction as a set of layers, with each layer building upon another layer (Figure 5-5). This method conceptualizes interaction as an aggregate of each of the team interaction processes or media use processes. That is, at any point in time, interaction is the aggregate of the behaviors observed at that instant. For example, if the team is "doing" and "producing" and "initiating", the visualization shows three layers of interaction. If the team is "doing" and "describing", then the visualization shows two layers. The sum of the observable behaviors for a particular meeting interaction translates to a higher y-value for the meeting interaction. In this sense, the

visualizations reflect the richness of interaction in terms of the aggregate of observable behaviors from either the media use or interaction perspective.

I experimented with numerous operational definitions to generate layered Steplines and Sparklines. I used the formalized model of team interaction and media use (Chapter 2) as a starting point to develop operational definitions using MIA-coded data to generate team interaction and media use Steplines. Two examples of these are Formulas 5-1 and 5-2. The first example is a formula for operationalizing differences in team interaction that sums the values for each team interaction construct (see Table 5-1) for each meeting interaction. Each team interaction construct is represented by a binary value of 0 or 1 where 1 represents the occurrence of the behavior during the meeting interaction. Table 5-1, for example, shows the result of applying this formula to the meeting interactions for Case Example D. Figure 5-5 shows a series of layered Team Interaction Steplines that use these t_x values. The second example is a formula for operationalizing differences in media use, *M*, that sums the values for the high-level process constructs using a range of values to distinguish between levels of access and interactivity. Figure 5-6 shows a series of "layered" Media Use Steplines that use the M values calculated using Formula 5-2.

Formula 5-1: Operational definition for the Team Interaction construct. The definition sums values for each of the team interaction process behaviors.

$$T = team\ interaction = communication + reaction + action = C + R + A$$

Each meeting interaction i_n is associated with a set of interaction behaviors, B, consisting of behaviors translated from the MIA keywords:

$$B_n = \{b_{grounding}, b_{explaining}, b_{structuring}, b_{initiating}, b_{responding}, b_{expressing}, \ldots . b_x\}$$

where:

b_x = 1 if behavior is observed or b_x = 0 if behavior is not observed. For example, if a meeting interaction has the keyword "walkthrough", $b_{grounding} = 1$.

Using these behaviors, the value for team interaction for each interaction, i_n, is the sum of the behaviors associated with each of the team interaction processes:

$$communication = C = b_{grounding} + b_{explaining} + b_{structuring} + b_{initiating} + b_{responding}$$
$$reaction = R = b_{expressing}$$
$$action = A = b_{doing} + b_{coordinating} + b_{producing} + b_{acting}$$

such that team interaction, t_n, for each meeting interaction is:

$$t_n = (c_n + r_n + a_n)$$

The stepline is generated using the value, t_x, plotted to the start and end times for i_x:

$$T_{stepline} = f(i_{start}, i_{end}, t_n)$$

Table 5-1: Example of data table resulting from assignment of binary values to MIA processes for each interaction segment.

Time (min) i_{start}	$i_{transcript}$	Doing	Grounding	Expressing	Structuring	Coordinating	Explaining	Initiating	Responding	Producing	Acting	c_n	r_n	a_n	t_n
15.28	A097: Mike, what do you got there	1	1	0	0	0	0	1	0	0	1	2	0	2	4
15.30	B098: Looks like a 1" pipe	1	1	0	0	0	0	0	1	0	1	2	0	2	4
15.36	Z099: ((laughter))	0	0	1	0	0	0	0	0	0	1	0	1	1	2
15.46	A100: Right. Just go in unde the cable tray in the elbow?	1	1	0	0	0	0	1	1	1	1	2	0	3	5
15.49	B101: Yep.	1	1	1	0	0	0	0	0	1	1	1	1	3	5
15.53	A102: This can simply be dropped back here.	1	1	0	0	0	0	0	0	1	1	1	0	3	4
15.53	B103: Yep.	1	1	1	0	0	0	0	0	1	1	1	1	3	5
15.54	A104: Okay.	1	1	1	0	0	0	0	1	0	1	2	1	2	5
15.60	A105: H, go ahead and show it elbowed off of here.	1	1	0	1	0	0	0	0	1	1	2	0	3	5
15.64	D106: Turn right here?	1	1	0	1	0	0	1	1	1	1	3	0	3	6
15.69	A107: Turn right there ((using laser pointer)) turn right here.	1	1	0	1	0	0	1	0	1	1	3	0	3	6

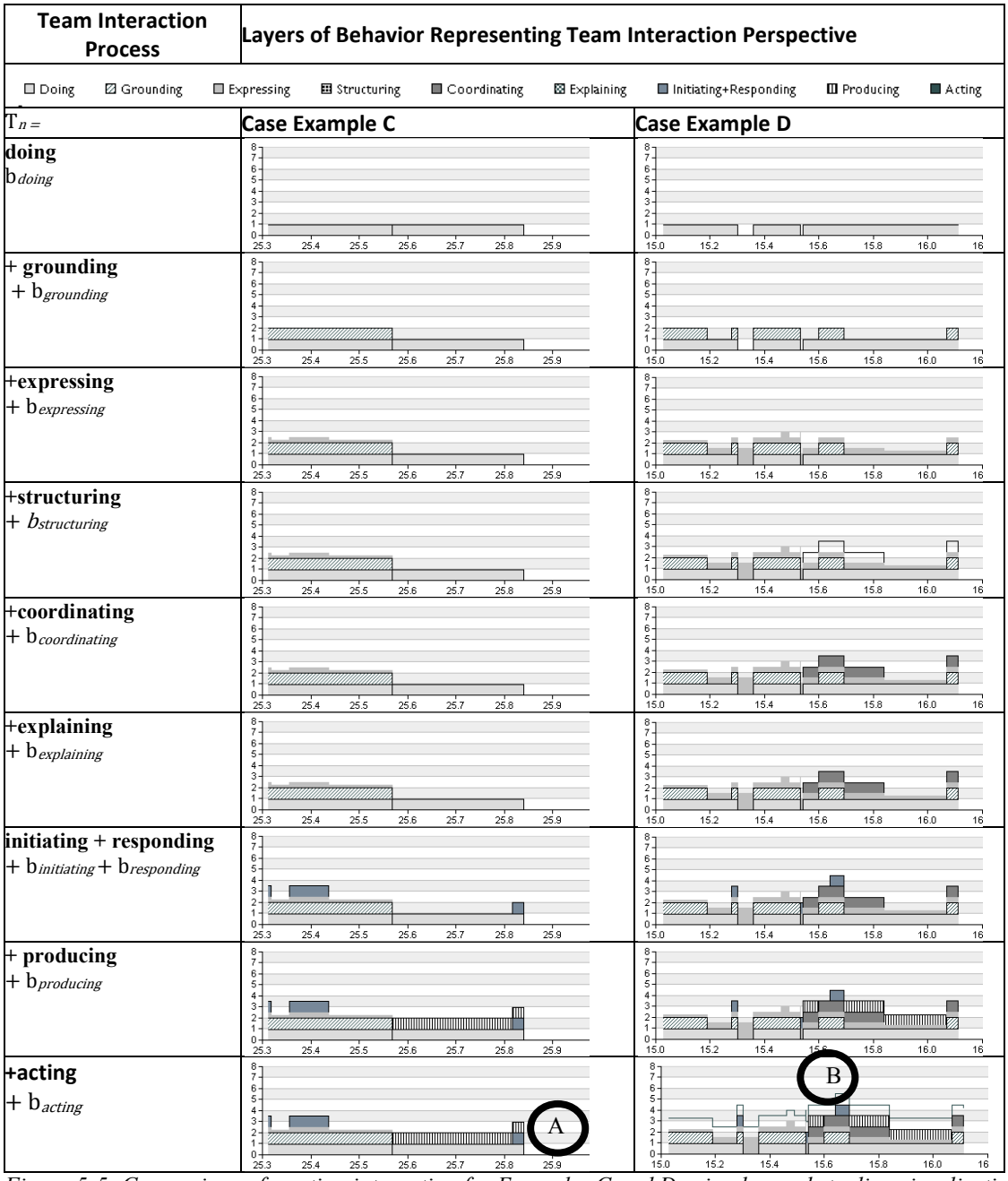


Figure 5-5: Comparison of meeting interaction for Examples C and D using layered stepline visualizations. This conceptualizes the notion of multi-purpose interaction since it combines the three levels of analysis and perspectives of team interaction, communication, reaction, and action. Differences in the number of layers over time reflect differences in the "richness" or amount of contributions the team makes to the project, process, and interpersonal interaction. Analysis of these layered Steplines shows the range of interaction, from periods with (A) no observed behaviors (or layers), to (B) periods of time with multiple behaviors.

Formula 5-2: An example of an operational definition for Media Use that sums each of the media use behaviors and uses different values for categorical states.

$$Media\ Use = \mathrm{M} = using + interacting + purposing$$

Each meeting interaction, i_n, is associated with a set of media use behaviors[8] consisting of ten behaviors translated from the MIA keywords:

$$B_n = \{b_{utilizing}, b_{interactivity}, b_{transitioning}, b_{accessing}, b_{purposing},\}$$

where:

$b_{utilizing}$ = 1 if behavior is observed or b = 0 if behavior is not observed
$b_{accessing}$ = (private = .25, semi-shared = .5, shared = 1.0)
$b_{transitioning}$= (viewing = .25, pointing = 5., annotating = .75, changing = 1.0)

$b_{interacting}$= (viewing = .25, pointing = 5., annotating = .75, changing = 1.0)
$b_{purposing}$= (describing = .25, explaining= 5., evaluating = .75, predicting/generating =1.0)

For example, if a meeting interaction has the keyword "annotating", $b_{interactivity} = .75$

Each team interaction process is calculated as a sum of the behaviors associated with the media use process:

$$using = MU_n = b_{utilizing} + b_{accessing} + b_{transitioning}$$
$$interacting = MI_n = b_{interacting}$$
$$purposing = MP_n = b_{purposing}$$

Such that media use, m_n, for each meeting interaction is the sum of these processes:

$$\mathrm{m}_n = (MU_n + MI_n + MP_n)$$

The Stepline is generated using the value, t_x, plotted to the start and end times for i_n:

$$\mathrm{M}_{stepline} = f(i_{\mathrm{start}}, i_{end}, \mathrm{m}_n)$$

Table 5-2: Example of data calculated to generate "layered" Steplines.

i_{start}	i_x	Utilizing	Accesing	Transitioning	Interacting	Purposing	m_n
15.28	A097: Mike, what do you got there	1	1	0	0.25	0.25	2.5
15.30	B098: Looks like a 1" pipe	1	1	0	0.25	0.25	2.5
15.36	Z099: *((laughter))*	0	0	0	0	0	0
15.46	A100: Right. Just go in under the cable tray in the elbow?	1	1	0	0.25	1	3.25
15.49	B101: Yep.	1	1	0	0.25	1	3.25
15.53	A102: This can simply be dropped back here.	1	1	0	0.5	1	3.5
15.53	B103: Yep.	1	1	0	0.25	1	3.25
15.54	A104: Okay.	0	0	0	0	0	0
15.60	A105: H, go ahead and show it elbowed off of here.	1	1	0	0.5	1	3.5
15.64	D106: Turn right here?	1	1	0	0.5	1	3.5
15.69	A107: Turn right there *((using laser pointer))* turn right here.	1	1	0	0.5	1	3.5
15.84	A108: This is going to be moved down to here. Draw a line right across here.	1	1	0	0.5	1	3.5

[8] McCowen et al. (2005) use a similar syntax to describe computational models to automate a system to recognize gestures and talking in meetings.

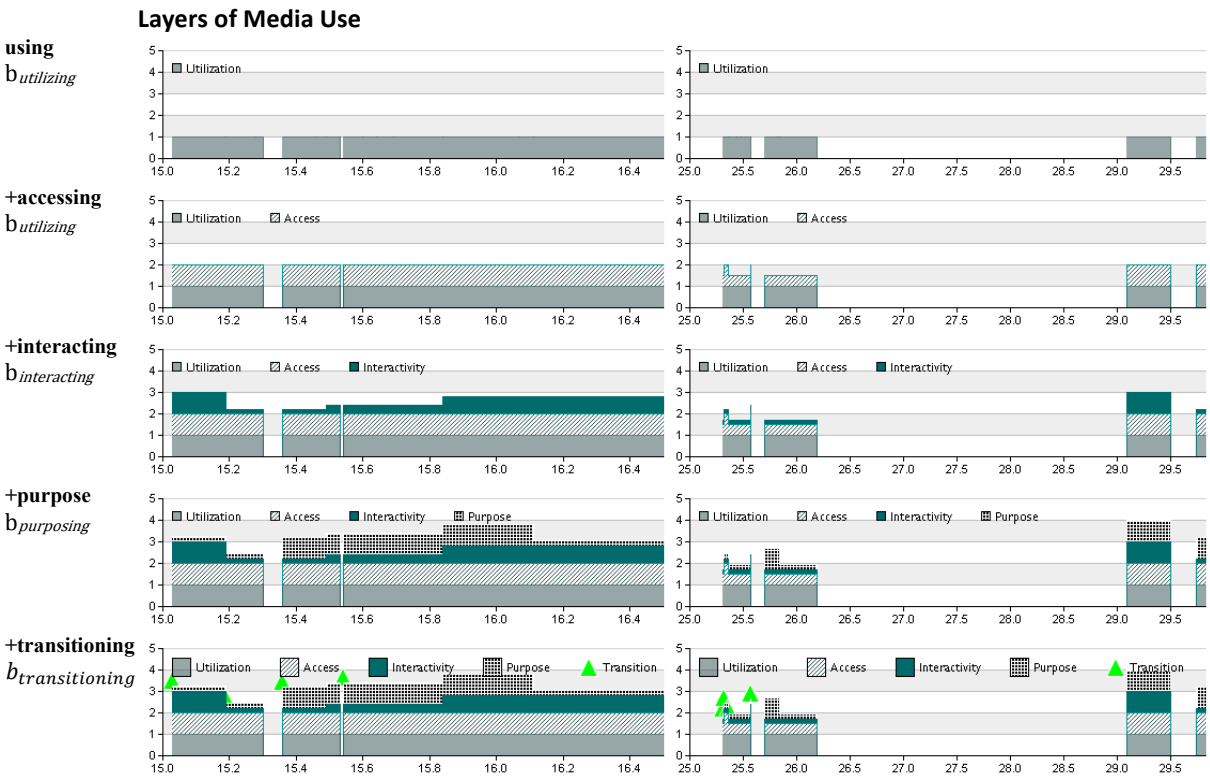


Figure 5-6: Layered Media Use Steplines comparing early conceptualization of the process of media use in Case Examples C and D. Subsequent conceptualizations of the media use process include nine layers of media use.

I used these Steplines to break the interaction into layers and identify the behaviors that best captured differences or commonalities in team interaction and media use. The Steplines in Figures 5-5 and 5-6 demonstrate the layering process I performed to visualize T and M. I generated hundreds of these Steplines and Sparklines and experimented with different operational definitions for T and M as well as with ordering of the layers. The generation of these visualizations was largely experimental at first, guided by intuition and the goal to describe the nuances in meeting observation I observed. As I observed and analyzed more meetings, I used the analytic data from MIA analysis (Chapter 4), literature review, and observational insight to guide this process.

Three features of the visualizations and, in turn, my conceptualization of interaction emerged from this process. First, each perspective has distinct "zones" of behavior that distinguish aspects of meeting interaction. Each perspective has a base layer or zone upon which all other behaviors depend. Team interaction, for example, begins with the basic processes of "doing" and "exchanging" and media use with the process of "utilizing". When teams are digressing and not communicating, none of the other team interaction behaviors are observable. Similarly, if the team is not using any media, then no other media use behaviors are observable.

Team interaction has a "typical" zone or set of behaviors that are occur more frequently in all the observations. These are the typical behaviors of "describing" and "relating". Media use, on the other hand,

fits into zones of use that reflect the frequency, level of engagement, and integration of media use into the process. There is no "typical" media use. When the operational definitions order the behaviors into these zones, the visualizations not only capture the aggregation of behaviors, but also provide a way to describe changes from typical to atypical team interaction behavior and from low to high media use.

Second, ordering of the layers captures the relative value of importance of particular behaviors and reflects key differences in meeting interaction. The layered diagrams that best capture what the nuances I observed were those with a differentiating layer on top. For example, the top layer in Figure 5-4 is "acting". I identified this layer of analysis late in the research, but it describes a key difference between meetings. Without this layer, it was difficult to see differences in the team interaction. Similarly, I identified the "performing" layer of media later in the research.

Third, over time I began to interpret the y-value of team interaction visualizations as process gains and losses. This led to examination of considering the relative value of contributions for various team interaction behaviors. The initial approach as shown in Formula 5-1 equalizes all contributions. "Disagreeing" makes the same contribution to the reaction process as "agreeing"; "describing" makes the same contributions to communicating as "explaining." As I experimented with different values, I examined the MIA analysis data, including the frequencies and variability of behaviors (Table 4-17), the literature review, and findings from previous studies related to gains and losses. I paid careful attention to the rationale for assigning relative values to different categories. For example, one operational definition of "communicating" I developed associated "explaining" with a 1.0 and "grounding" with .5. This approach conveyed differences in teams that sought deeper understanding to those that were clarifying or simply taking stock.

For the media use perspective, I interpreted differences in the stepline y-value as richness of media use or differences in the extent to which teams used media in all aspects of meeting interaction. I developed operational definitions of the media use process using these Steplines, relying on MIA analytic data and literature as guidance. For example, I initially assigned relative values to the various coding categories for "interactivity" based on the frequency of observing different behaviors. I assigned "viewing" a value of .25, "pointing" a value of .5, "changing" a value of .75, and "annotating" a value of 1.0 since I observed "annotating" less frequently than the other behaviors. Although "changing" was observed more frequently than "annotating", "changing" is a richer interaction since it demonstrates active engagement with the media, changing the content of the media, and integration of media use in the meeting interaction to produce project information. Thus, the operational definition that best reflects the differences in media use is one where "changing" is associated with a value of 1.0 and "annotating" with a value of .75.

The layered steplines acted as tools to operationalize my conceptualization of interaction, and, in turn, the visualizations influenced my model of meeting interaction. These steplines were an intermediary step and from these visualizations I developed the notion of viewing changes in behavior along a spectrum of behavior that captures the movement between zones of behavior. The following section discusses the formalization of this method.

5.4 Interaction Spectrum Method

I developed the Interaction Spectrum Method to order and visualize categorical, temporal-based data relative to a set of criteria along a spectrum. The spectrum acts as a framework to order categorical data relative to endpoints that define the range of interaction and to structure the data into" interaction zones". As an example, let us consider ordering "level of interactivity" categorical data using a spectrum. The categories implicitly define the range of behavior. Let us define the criteria for this spectrum as "typical" behavior such that one end of the spectrum represents the most frequently observed behavior and the other end of the spectrum as least frequently observed behavior. Using the MIA-coded data, the initial ordering would be "none, annotating, changing, pointing, viewing". The simplest method to organize these along the spectrum is to segment the spectrum into four parts (zones) and assign the values in order. The final step is mapping coded data to the range.

Figure 5-7 shows two examples of ordering values along the spectrum. The first Figure 5-7 (B) distributes the values equally. The second, Figure 5-7 (D) places "pointing" closer to "viewing" and "changing" closer to "markup" since "pointing" was observed more frequently than "changing". Neither approach is correct or incorrect. The goal for the researcher is to define how to interpret the Y-value differences and the rationale for the ordering. Adding zones to the diagram serve to help interpretation and communicate the rationale for the ordering. The zones act as additional guides to interpret those differences. In this case the "atypical" zone where an upper range is the least commonly observed behavior, and the lowest, the most commonly observed behavior, and movement along the vertical axis represent the zones and movement represent interaction that is moving toward typical or atypical behavior.

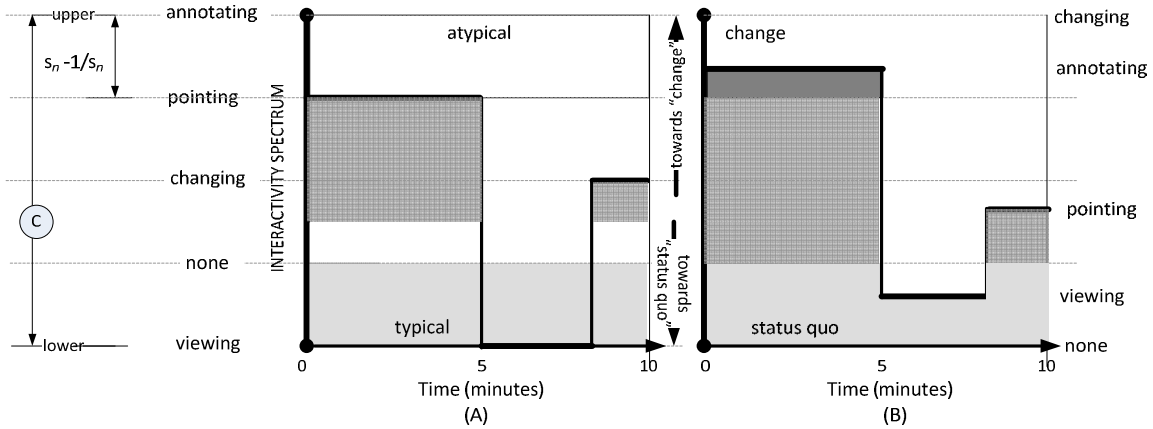


Figure 5-7: Conceptualization of a generic spectrum method. (A) The range of values defined by an upper and lower value for the spectrum endpoints. (B) An "interactivity" spectrum segmented using equal distribution for categories and ordered based on frequency of observation. (C) "Status quo" zone showing behavior that is typical. (D) An "interactivity" spectrum segmented using unequal distribution for categories.

I refer to this process of ordering and visualizing a range of categorical data using a set of ordering criteria as the Interaction Spectrum Method (ISM). This method establishes a range of interaction, establishes variations in interaction relative to one another to represent some model of interaction, e.g., a normative, typical, or other model. It communicates transitions, frequencies, and flow in a manner that is suitable for comparison and interpretation. The spectrum method applies to ranked categorical data and addresses several of the shortcomings of prior approaches. It conveys the temporal states and changes between states relative to a "defined" standard.

In summary, the Interaction Spectrum Method involves the following steps:

1. Select an analytic perspective(s).
2. Identify the categories that capture the states for that perspective and represent the range of the behavioral states (Chapter 2 and Chapter 4 discuss the categories of analysis in this dissertation).
3. Identify the criteria for ordering states of spectrum: transitional, process, value-based
4. Define the behaviors associated with spectrum endpoint in y-axis.
5. Define the spectrum segmentations.
6. Define rules to associate coded categories along the spectrum.
7. Generate sparkline or stepline to visualize the spectrum.

The following sections demonstrate ISM, and use ISM to visualize and operationalize the two primary constructs in this research: team interaction and media use. Each section, Sections 5.5 and 5.6, begins with the criteria to order categories and the rationale for ordering behaviors along the spectrum (Steps 3-6). Each section concludes with a discussion of the key findings from applying the method to describe and compare meeting interaction.

5.5 Richness of Interaction Spectrum

The goal of the Richness of Interaction spectrum is to describe differences in how the team interacts. MIA describes the categorical states and range of behavior for this perspective (Step 2 in ISM method). Two competing criteria guided the development of this spectrum. First, meeting interactions differ in the nature and amount of contributions they make to the project, meeting process, and interpersonal interactions. This emphasis on small, micro-interaction behavior relative to different systems within which the interaction takes place is a fundamental assumption in MIM (see Chapter 4). Using this assumption as a criterion, the ordering of meeting interaction along this spectrum is a function of the amount of contributions the meeting interactions make to these meeting systems—the project, meeting process, and interpersonal interactions. One end of the spectrum represents interactions that make no contributions to any meeting system; the other end of the spectrum represents interactions that make multiple contributions to each of the meeting systems. Each meeting interaction is assessable in terms of the contributions it makes to these systems. The zones of interaction are distinguishable in terms of differences in the amount

of those contributions, for example, low, medium, and high. I will address the issues of quantifying these contributions and establishing the maximum value of those contributions later in this section.

The second criterion describes differences relative to a standard that uses observed, instead of ideal, behavior as a comparison. Rather than artificially define what the theoretical maximum contributions of meeting interaction should be, I used the observations to define the range of behavior: which behaviors represent the maximum contributions and which behaviors represent minimal contributions. I identified three zones of team interaction: 1) status quo or typical interaction, occurring more frequently and in all meeting interactions while making average contributions to the meeting systems, 2) atypical in terms of negative or undesirable behavior while making few to no contributions, and 3) atypical in terms of positive or more desirable behavior while making contributions to multiple systems, i.e, the project, meeting process, and interpersonal interactions (see Section 2.2.3).

I use the term *synergy* to describe the atypical, desirable behavior that results in multiple contributions to interaction, process, and project. Hackman uses the synergy construct in his research on team behavior, and describes synergy as when process losses are minimized and teams make a "shared commitment to the team and its work" (Hackman 1987, p. 325). Hackman did not operationalize the synergy construct. The dictionary definition of synergy is "increased effectiveness, achievement, etc., produced as a result of combined action or co-operation" (Oxford English Dictionary 1989). Synergy describes the meeting interaction during which the team focuses, reacts positively to one another, produces, and acts on issues. Synergy is the upper range of team interaction. Synergy is the culmination of activities that lead to cooperative action and resolution of project issues.

I define the atypical, undesirable behavior that makes no contributions as "breakdown". The dictionary definition of breakdown is "the act or process of failing to function or continue. The condition resulting from this: *a breakdown in communication*" (American Heritage® Dictionary 2009). Breakdown describes the rare moments in meeting interaction when the team members stop communicating or acting and react negatively towards one another. Breakdowns are periods of inaction when efforts to communicate and address project issues fail, and the team reaches an impasse.

I use these concepts to organize the team interaction spectrum and create the structure for ordering interactions relative to three interaction zones (Figure 5-8).

- **breakdown:** meeting interaction during which the team members react negatively towards one another, fail to communicate, or act on any project-related issues.
- **status quo:** meeting interaction during which team members express no emotion, continue communication, or take stock of project and process issues.
- **synergy:** meeting interaction during which team members react positively towards one another, address, resolve, or commit to resolve issues.

Using these three "zones" as guides, I defined two intermediate zones to further distinguish periods of interaction.

- **towards breakdown:** meeting interaction during which team members focus on project-related activity with conflict, disagreement, and inaction.
- **towards synergy:** meeting interaction during which the team members focus on project-related activity, seek deeper understanding, or structure the interaction.

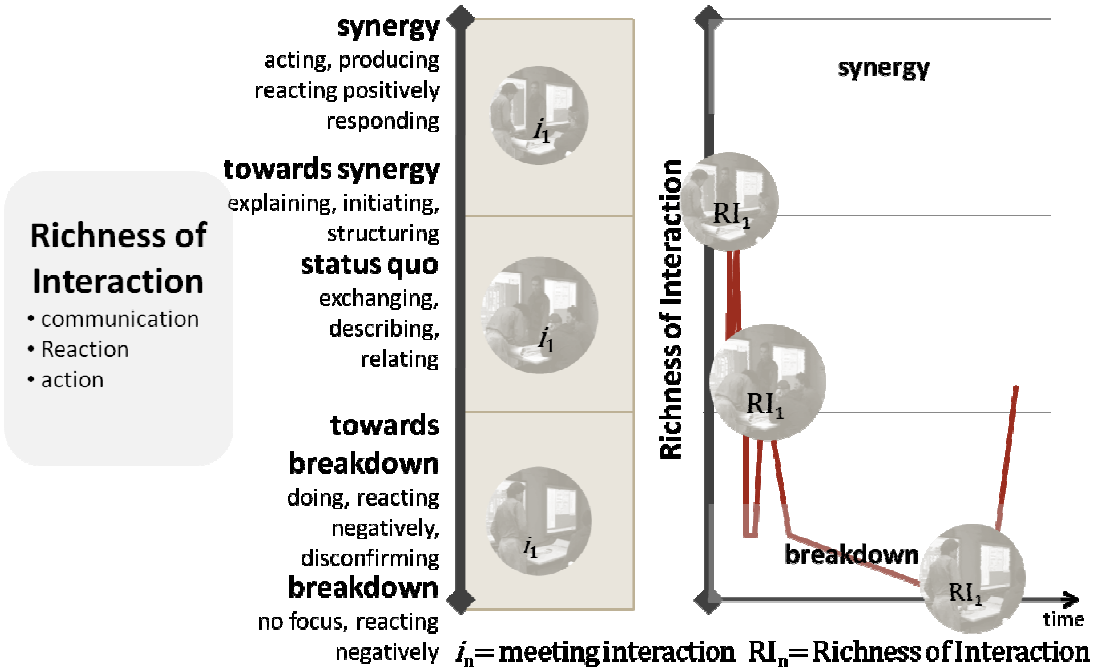


Figure 5-8: The conceptual framework for the Richness of Interaction spectrum. The Richness of Interaction spectrum describes the range of team behavior from breakdown to synergy. Using the interaction spectrum method, each meeting interaction, e.g., i_x, i_y, i_z, is associated with a value along this spectrum. The result is a Richness of Interaction sparkline that shows the changes in behavior over time and how meeting interaction changes from moment to moment relative to these interaction zones. This example shows meeting interaction that culminates in a breakdown.

I refer to the team interaction spectrum as the Richness of Interaction (RI) spectrum. RI spectrum represents the extent to which the team achieves synergy, as a function of the communication, reaction, and action behaviors observed, during a meeting interaction. RI acts as a conceptual framework to describe and interpret differences in meeting interaction relative to their contributions to meeting systems and relative to differences in communication, reaction, and action processes.

The sixth step in the interaction spectrum method is to develop the operational definitions for the spectrum. The development of the operational definitions incorporated findings from the MIA analyses, the descriptions of the zones, and findings in the literature. Formula 5-3 is the operational definition for the Richness of Interaction construct.

Formula 5-3: A formalized definition of Richness of Interaction, RI*, to describe and compare differences in moment-to-moment interaction from the team interaction perspective.*

$$\boldsymbol{Richness\ of\ Interaction\ (RI) = \mathbf{G}}$$

where *RI* is equal to the sum of the contributions from each of the observed team interaction behaviors to project, meeting process, and interpersonal interactions:

for each $\boldsymbol{i_n}$ *in I:*

$$\mathrm{RI_n} = G_n = G_C^n + G_R^n + G_A^n$$

$$G_C^n = b_{exchanging} * (b_{relating} + b_{grounding} + b_{structuring})$$
$$G_R^n = b_{expressing} + b_{conflicting}$$
$$G_A^n = b_{doing} * (b_{coordinating} + b_{responding} + b_{producing} + b_{acting})$$

where b_x is equal to the value listed in Table 5-3.

RI for a meeting is equal to:

$$\mathrm{RI} = \frac{\sum_{n=0}^{N} \mathrm{RI_n} * \mathrm{d_n}}{D}$$

where d_n is equal to the duration of the nth interaction and D is the duration of the meeting.

The contribution of each meeting interaction, $\boldsymbol{G_n}$, is equal to the sum of the contributions from each of the communication, reaction, and action behaviors associated with the meeting interaction. I used the definitions of the zones to associate behaviors with different relative values ranging from 0 to 1.5 as listed in Table 5.3. This Richness of Interaction construct represents a model of team interaction that makes the following assumptions in its operational definition:

1. Differences in team interaction are a function of communication, reaction, and action.
2. Every meeting interaction, $\boldsymbol{i_n}$, is purposeful and viewed in relation to meeting interaction preceding and subsequent to the interaction. Some interactions, while making no direct contributions, serve a purpose when viewed in relation to other interactions.
3. Exchanging ($b_{exchanging}$), doing (b_{doing}), and not reacting negatively are the "building blocks" of team interaction and keep teams from experiencing breakdowns.
4. Process gains and losses are the changes from one interaction to another and represent differences in contributions from one meeting interaction to another.
5. Communication behaviors, G_C^n, make relative contributions to shared understanding of the project, from describing to summarizing, to stating goals and explaining.
6. Communication behaviors, C_n, make relative contributions to relational interaction, from disconfirming to continuing, to initiating, to responding.
7. Reaction behaviors, G_R^n, make relative contributions to team cohesiveness and personal satisfaction, from negative expressions to simple disagreements, to no expressions, to simple agreements, to positive expressions.
8. Action behaviors, G_A^n, make relative contributions to project and process goals, from structuring to managing and identifying issues, to producing, to acting on issues and engaging in closed-loop communication.

The table shows the MIA codes associated with the various MIA processes and their values. For example, b_{acting} is equal to 1.5 since it represents contributions to project, process, and interpersonal interactions, representing closed-loop communication (Section 2.3.1).

Table 5-3: Values for b_x for MIA codes and processes. Behaviors associated with synergy, for example, are equal to 1.5 and behaviors associated with breakdown are equal to 0. The assignment of values and order is based on the literature review, analyses in Chapter 4, and the production of the layered steplines.

increasing contributions to project, process, or interpersonal interactions

less frequently observed behaviors | less frequently observed behaviors

Level of Analysis	Process	Process	Breakdown	Towards breakdown	Status Quo			Towards synergy	Synergy
		Value	**0**	**+.25**	**+.5**	**+.75**	**+1.0**	**+1.25**	**+1.5**
Project	Action	Acting							acting
	Action	Producing					issue	generate/ evaluate/ predict	
	Communication	Grounding (describing and explaining)	digression	communication	walkthrough describe	summary	criteria explain		
Process	Communication	Structuring				gives suggestion		goal	
	Action	Coordinating		order			manage		
Interpersonal Interaction	Reaction	Expressing and Conflicting	shows tension/ antagonism	disagrees	no negative or positive expression		agrees		shows tension release /solidarity
	Communication	Relating (initiating and responding)	disconfirm		continue	initiate		respond	

Table 5-4: Examples of b_x and i_n for different sets of team interaction behaviors, B, represented by the MIA codes in the columns. The table shows how different sets of team interaction behaviors result in different values for Richness of Interaction, RI_n. Each MIA code translates to a value using Table 5-3. For example, "describing" translates to a value of .5. The sum of all b_x is equal to G_n, and G_n is normalized to create the RI_n value.

	B **MIA code for i_n**	b_x	**B** **MIA codes for i_n**	b_x	**B** **MIA code i_n**	b_x	**B** **MIA code for i_n**	b_x	**B** **MIA code for i_n**	b_x	**B** **MIA code fori_n**	b_x
Acting					acting	1.5	acting	1.5	acting	1.5	acting	1.5
Producing									issue	1.0	producing	1.25
Grounding (Describing and Explaining)			describing	0.50	describing	0.50	describing	0.50				
Structuring												
Coordinating												
Expressing (and Conflicting)	shows tension	0.0	disagrees	0.25	none	0.25	none	0. 5	none	0. 5	shows solidarity	1.5
Relating (Initiating and Responding)	none	0.0	continuing	0.5	initiating	0.75	continuing	0.5	initiating	0.75	responding	1.25
G_C^n		0.0		1.0		1.25		1.0		0.75		1.25
G_R^n		0.0		0.25		0.25		0.5		0. 5		1.5
G_A^n		0.0		0.0		1.5		1.5		2.5		2.75
$\mathbf{G_n \sum b_x}$		**0.0**		**1.25**		**2.25**		**3.0**		**3.75**		**5.5**
$\mathbf{RI_n = \frac{3}{5.75} * RI_n}$		**0.00**		**0.68**		**1.23**		**1.63**		**2.05**		**3.0**
RI zone	breakdown		towards breakdown		status quo		status quo		towards synergy		synergy	

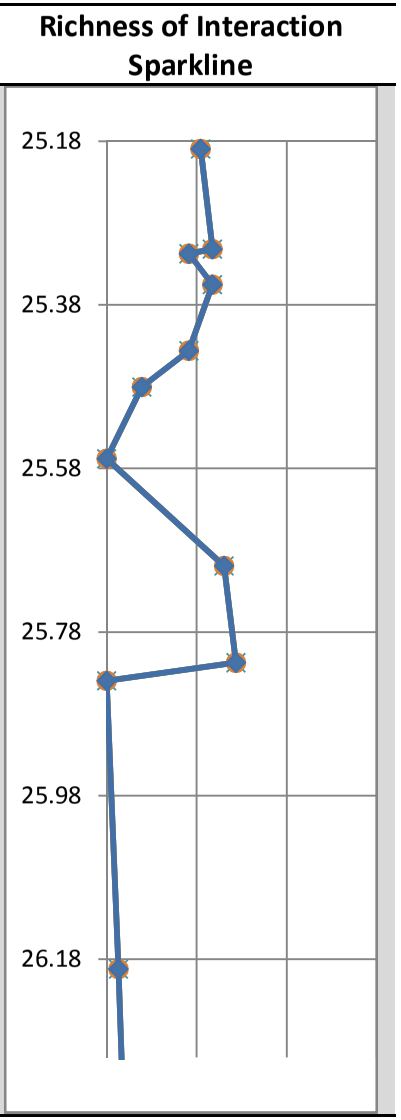
The final step in calculating RI_n is to normalize the values using the maximum RI_n. I applied the operational definition to all 4,689 meeting interactions in Phase IV (see Chapter 3) to calculate the maximum RI_n=5.25. Since the Richness of Interaction Spectrum has three zones, all RI values are normalized to 3; thus, RI_n ranges from 0 to 3, with 0 representing breakdown and 3 representing synergy, while values between 1 and 2 represent status quo (Table 5-5). Table 5-6 shows the results of applying the operational definition for Richness of Interaction formulas to Case Example C and shows a Sparkline, turned orthogonally, parallel to the transcript.

Table 5-5:Values for Richness of Interaction Spectrum Zones

Zones	Value	Characteristics
breakdown	$RI_n = 0$	Team is reacting negatively and not communicating or acting.
towards breakdown	$0 < RI_n \leq 1$	Team is reacting negatively, grounding or engaged in one-way communication.
status quo	$1 < RI_n \leq 2$	Team is grounding and relating.
towards synergy	$2 < RI_n \leq 3$	Team is coordinating, structuring, explaining, and initiating.
synergy	$RI_n = 3$	Team is producing, responding, reacting positively, and acting on issues.

Table 5-6: Richness of Interaction values, RI_n, for meeting interactions, i, in Case Example C (Chapter 1). The rotated sparkline aligns the values for RI on the sparkline with the meeting interaction. The Y-axis is the meeting time.

Segment Text	Workflow	Relational	IPA	Purpose	G_C^n	G_R^n	G_A^n	RI_n
A177: You think the 10' wall is coincident with that wall on the mezzanine catwalk. That's what you are telling me?	clarification	initiation	asks for orientation	describe	1.5	0.5	0	1.04
C178: ...that's what the drawing says. Yes.	clarification	response	gives orientation	describe	1.75	0.5	0	1.17
A179: I don't believe that is true. Because you don't have a mezzanine drawing to show me.	clarification	initiation	disagrees	describe	1.5	0.25	0	0.91
C180: I have a reflected ceiling pattern that says...	clarification	response	gives orientation	describe	1.75	0.5	0	1.17
A181: but you don't have the catwalk above it	clarification	initiation	disagrees	describe	1.5	0.25	0	0.91
Y182: *((looking at drawing))*	walkthrough	other	NA	describe	0.5	0.25	0	0.39
A183: This is perfect.	other	other	shows tension	describe	0	0	0	0.00
A185: Okay. So if that's not true, Can I make 10'5 ceiling coincident with that wall?	alternative	initiation	shows tension	generate	1	0	1.5	1.30
C186: Sure.	alternative	response	shows tension	evaluate	1.25	0	1.5	1.44
Y187: *((looking at drawings))*	walkthrough	other	shows tension	describe	0	0	0	0.00
Z188: *((various conversations, looking at drawings, whiteboard)) ((having conversations to work through issues))*	digression	other	NA	NA	0	0.25	0	0.13



5.5.1 Findings Using Richness of Interaction Spectra

Richness of Interaction Sparklines and Steplines visually communicate the changes in moment-to-moment interaction from the team interaction perspectives. For example, Figure 5-9 compares meeting interaction for the four Case Examples (Chapter 1, Section 1.1.1) using Richness of Interaction Steplines. This comparison shows the following differences:

- *time spent in the interaction zones:* Teams B and D spent the majority of the time interacting "towards synergy", whereas Teams A and C spent the majority of time in the "breakdown" zone.
- *range of interaction:* Team A interaction hovers around the "status quo" transition, whereas Team C moves towards synergy and then towards a breakdown. Teams B and D move between periods of "status quo" and periods of synergy, with Team B reaching a period of synergy.
- *rhythm of interaction:* Teams A and B is a "flat line" with little change in interaction, whereas Team D is dynamic with respect to the nature of the interaction.
-

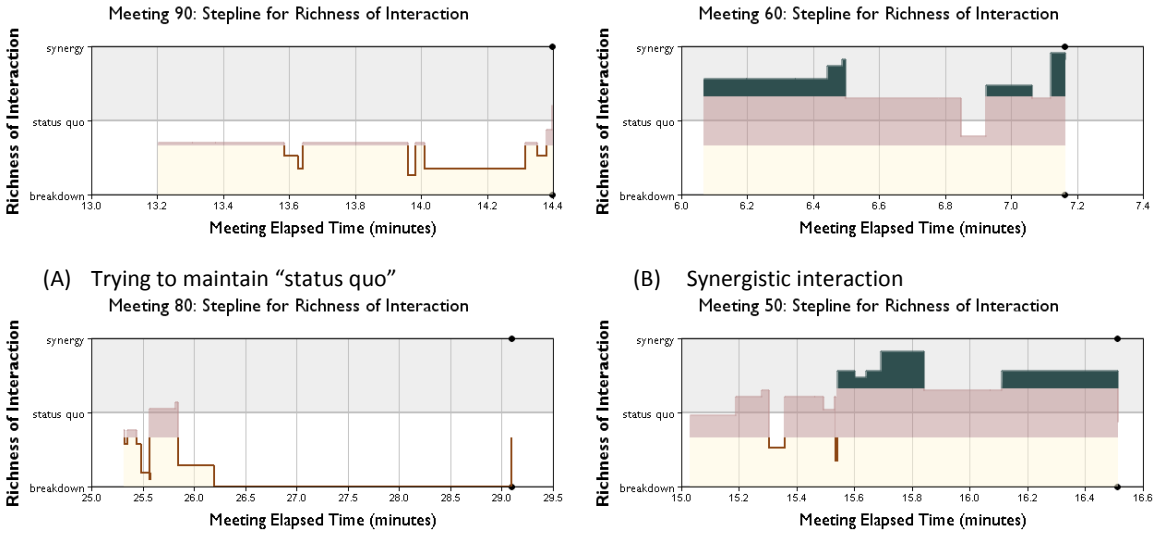


Figure 5-9: Comparison of Richness of Interaction Sparklines for the Case Examples. The Interaction Sparklines show differences in the time spent in the "interaction" zones and the movement between those zones.

These examples and the examples in Figure 5-10 illustrate several patterns of interaction that recur throughout meetings. These patterns show how most teams rarely deviate from a pattern of interaction established early in the meeting. Teams establish a pattern of interaction and repeat that pattern throughout the meeting.

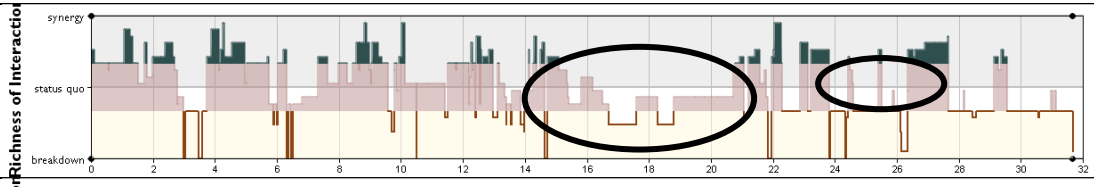
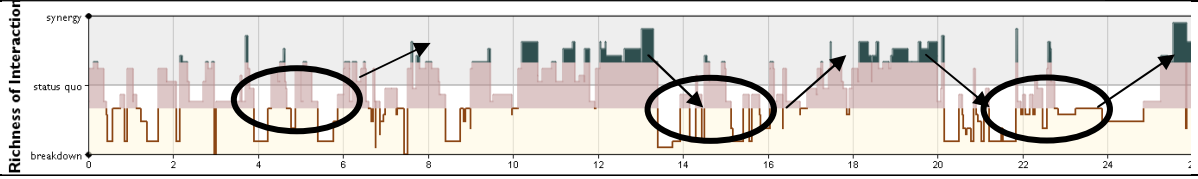
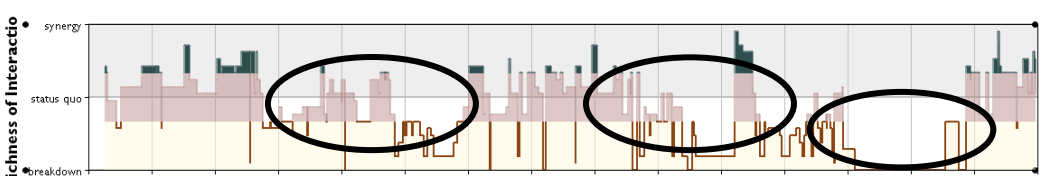
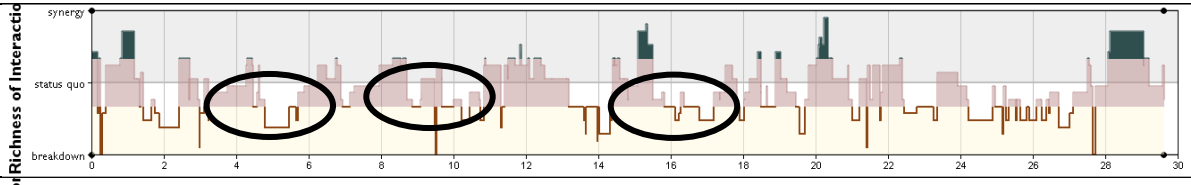
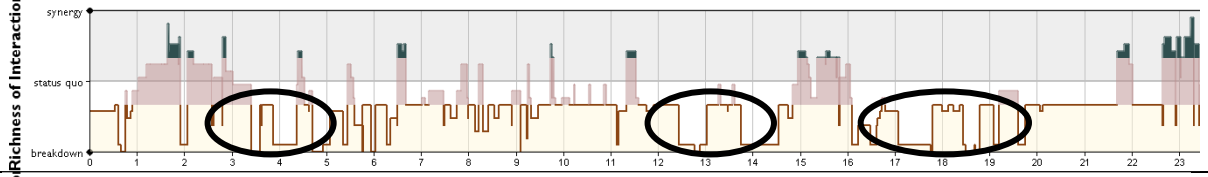
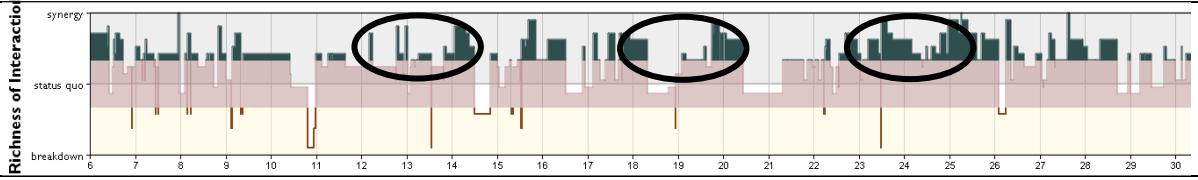
	(A) Maintain status quo. These are periods during which the team stays within the status quo zone.
	(B) Synergy to status quo to breakdown. These are periods during which the team moves from breakdowns through status quo to synergy and then to status quo and back to breakdowns.
	(C) No rhythm and prolonged breakdowns. Prolonged breakdowns do not follow periods of synergy but rather periods where the team is trying to maintain status quo.
	(D) Cyclical Status Quo, brief periods towards synergy and breakdown.
	(E) Towards breakdown and flat lines. Flatlines recur within the same meetings.
	(F) Cyclical, rhythmic synergy. These are patterns during which the team cycles through periods of synergy with brief periods of time spent in status quo.

Figure 5-10: Richness of Interaction Spectra illustrate six distinct patterns of team interaction and how the overall pattern of interaction rarely changes over the course of a meeting.

The characteristics of team interaction patterns (Figure 5-10) that recur are

a) *breakdown patterns (Figure 5-10[C] and parts of [B]):* the trend is downward toward the breakdown zone and no synergistic activity takes place.
b) *resting patterns (Figure 5-10[D] and parts of [A]):* the meeting interaction stays within the status quo zone and neither synergy nor breakdowns occur.
c) *synergistic patterns (Figure 5-10[F] and parts of [B])*: the meeting interaction takes place in the synergistic range of interaction and the interaction moves from status quo to synergy.
d) *flatline (Figure 5-10[E]):* periods of time when the rate of activity is greatly reduced or no activity takes place.
e) *cyclical patterns (Figure 5-10[B] and [F])*: wide range across the spectra or periods of time when the team moves across the interaction zone several times between synergy and breakdown.

Some teams develop a rhythm (Figure 5-10[F]), whereas others exhibit irregular (Figure 5-10[C]). The rhythm and flow of the meetings are a critical aspect of meeting interaction the RI value for a meeting, such as 1.5, does not capture this aspect and demonstrates the challenge of abstracting interaction to a single number.

Some key findings from the review of the RI Steplines and these patterns include the following:

- Breakdowns and synergies are rare. Only two complete breakdowns—a period of more than thirty seconds where team members did not communicate and reacted negatively towards one another—occurred.
- Teams repeat synergistic patterns whereas breakdown patterns are more variable.
- Management facilitation is a common element in synergistic patterns. The coincidence of the cyclical movement in Figure 5-10[F], for example, occurs with "managing" or "structuring" interactions. This is missing from the irregular meeting interaction.

The Richness of Interaction spectra also support comparative analysis of the time spent in each team interaction zone (Figure 5-11 and Table 5-7). The teams spent on average 58% (σ=.08) of their time in the "status quo" zone, 20% (σ=.09) in the breakdown zone, and 22% (σ=.08) in the synergy zone. On average, there were .5 breakdowns per meeting and 2.9 synergies per meeting with 8 occurrences of synergy in one meeting, Meeting 60. Meeting 50 was the most synergistic with the team spending 35% of the time "towards" synergy and only 8% "towards breakdown". This reflects the focused, productive nature of the meeting activity. The team in Meeting 80 spent the most time in the breakdown zone, 37%. Meeting 1 represents a meeting with status quo interaction.

This zone analysis serves several purposes. It provides data to ensure that the operational definitions for the spectra measure what I intended the Richness of Interaction values to measure. The goal was to develop an operational definition such that a majority of the RI values fall within the status quo range. The average value for Richness of Interaction for the overall meetings is 1.49 (Table 5-7) with values ranging from 1.78 (Meeting 60) to 1.25 (Meeting 80). Meeting 60 has the highest overall Richness of Interaction value but had less time spent in the synergy zone. Meeting 60 had more complete synergy interactions than

Meeting 50. The RI value provides a standard construct to compare team interaction, but it reduces the interaction to a single multi-categorical construct. Describing and comparing meetings based on time spent in "breakdown", "status quo", and "synergy" is a better descriptor of differences in the team interaction than a single construct, such as productivity, satisfaction, or effectiveness that are commonly used in studies of team interaction (Chapter 2).

As further evidence for the Richness of Interaction construct, I compared the RI values to the satisfaction data (Table 5-7, see Appendix D for discussion of satisfaction data). The two meetings with the highest satisfaction values have the two highest RI values, and most notably the highest percentages of time spent in the synergy zone. This suggests that time spent in synergy contributes to personal satisfaction and group satisfaction with the meeting process.

Two issues persist related to the Richness of Interaction Spectrum and the operationalization of the RI construct. The variations in the overall RI values are small and do not sufficiently communicate the differences in team interaction I observed. The interaction zone analysis captures some of these differences, but still does not communicate some aspects of the interaction such as the effects of interaction length, meeting length, or limited participation by some meeting participants. Additionally, positive and negative expressions occur rarely, and the current definitions may not weight these appropriately. These are issues for future researchers to consider and address. I spent significant time experimenting with the underlying formulas to translate the coded data to a point along the RI spectrum, while recognizing that the operational definitions are just one possible way to describe differences in the team interaction.

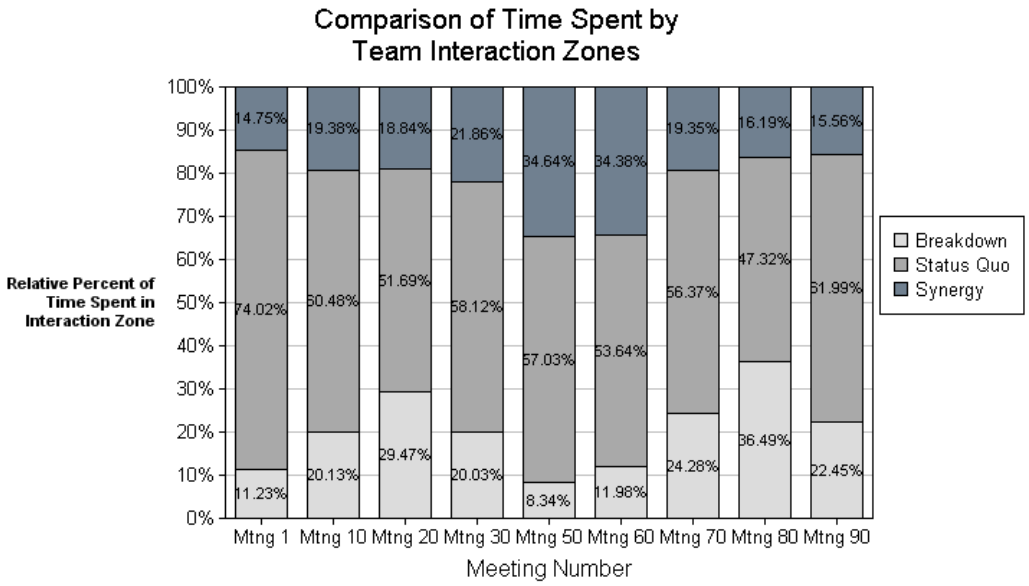


Figure 5-11: Comparison of time spent by team interaction zones for the nine meetings.

Table 5-7: Summary of time spent within each range of the Richness of Interaction spectrum. The data show that the majority of time spent is in the middle range of the spectrum.

	Richness of Interaction: % of Time Spent in Spectrum Zone			Richness of Interaction (range from 0 to 3.0)[1]	Satisfaction Value[2]
Meeting	Breakdown	Interacting	Synergy		
60	12%	54%	34%	1.78	6.39
50	8%	57%	35%	1.75	5.21
1	11%	74%	15%	1.58	
90	23%	62%	16%	1.44	4.43
20	30%	52%	19%	1.43	
30	20%	58%	22%	1.42	
70	24%	56%	19%	1.42	
10	20%	61%	19%	1.37	
80	37%	47%	16%	1.25	4.86
$\bar{x}$	20%	58%	22%	1.49	
σ	.09	.08	.08	0.18	
minimum	8.3%	47.3%	14.7%	1.25	
maximum	36.5%	74.0%	34.6%	1.78	

[1]Value ranges from 0, breakdown, to 3.0 representing synergy.

[2]See Appendix D for a discussion of satisfaction survey results.

5.6 Richness of Media Use Spectrum

The Richness of Media Use (*RMU*) spectrum represents the range of media use and the extent to which teams collectively use shared media to communicate, react, and act at the project, process, and interpersonal level (Figure 5-12). Operationalization of *RMU* integrates the three media use constructs: use, interactivity, and purpose. This spectrum is process-based whereas RI is value-based. There is a wider range of media use behaviors compared to team interaction, e.g., there was no "typical" media use. Instead, what I observed and the analyses in Chapter 4 describe, are different levels of media use distinguished by the following "zones of interaction":

- ***no use:*** periods of time when the team is using no media.
- ***low use:*** periods of time when the team is using media to support communication.
- ***medium use:*** periods of time when the team uses semi-shared or shared media.
- ***high use:*** periods of time when the team uses shared media to explain, annotate and capture communication.
- ***rich use:*** periods of time when the team is highly engaged with media, cooperatively using media to address project issues.

Movements along the spectrum and across the RMU zones describe moment-to-moment differences in the extent to which the teams use media as well as the level of engagement with the media and how deeply they integrate the media into all team interaction processes at the three levels of analysis.. The thresholds between these zones represent the marked differences I observed. The threshold between low and medium use is the shift to shared use of media. The threshold between medium use and rich use is the difference in how teams interact with and use media to support action.

This Richness of Media Use spectrum represents a model of media use that makes the following assumptions:

- Differences in media use for any meeting interaction are a function of utilization, MU_{n}, access, interactivity, and instrumental purpose of the media use.
- Media utilization, *MU*, is the "building block" of media use and distinguishes any interaction from "no use".
- Accessing behaviors change in engagement from none to integrating, to sharing.
- Interacting behaviors change in engagement from supporting to directing, to annotating, to working.
- Purposing behaviors affect the integration of media use at the interaction, process, and project level and change in level of integration from communicating to coordinating, to working, to performing.
- The change from one level of media use to another level describes transitions as well as changes in other aspects of media use.

Formula 5-4 is the operational definition for RMU, and Table 5-8 lists the values for . Table 5-9 describes the range of values for RMU. Table 5-8 illustrates the calculation of RMU for Case Example C.

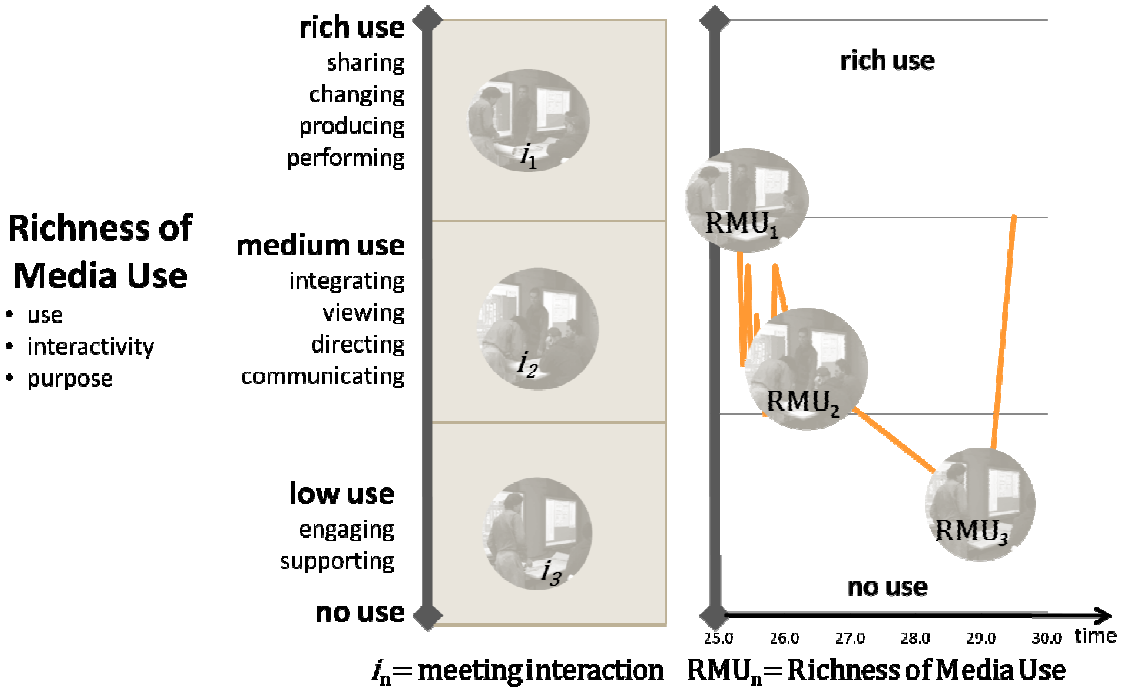


Figure 5-12: Conceptual framework for the Richness of Media Use spectrum. The spectrum consists of three media use zones, bounded on one end by "no use" and the other end "rich use." The spectrum represents the differences in how teams used media.

Formula 5-4: A formalized definition of Richness of Media Use to describe and compare differences in moment-to-moment media use.

$$Richness\ of\ Media\ Use\ =\ \boldsymbol{RMU}$$

where $\boldsymbol{RMU_n}$ is equal to the level of engagement and integration of media use at the project, process, and interpersonal interaction levels, such that for each i_n:

$$RMU_n\ =\ MU_n * (MA_n + MI_n + MP_n)$$

$MU_n = \boldsymbol{utilizing} = b_{utilizing}$
$MA_n = \boldsymbol{accessing} = b_{integrating} + b_{sharing}$
$MI_n = \boldsymbol{interacting} = b_{directing} + b_{supporting} + b_{working}$
$MP_n = \boldsymbol{purposing} = b_{performing} + b_{coordinating} + b_{coordinating}$

such that an operational definition for RMU_n for i_n with q media use behaviors is equal to the sum of the level of engagement and integration of media use for each media use behavior:

$$\mathbf{RMU_n}\ =\ \sum_{x=0}^{x=q} b_x$$

where b_x is equal to the value listed in Table 5-9. RMU for a meeting is equal to:

$$RMU = \frac{\sum_{n=0}^{n=N} RMU_n\ * D_n}{D}$$

where d_n is equal to the duration of the nth interaction and D is the duration of the meeting.

Table 5-8: Values for b_x for MIA codes and processes. Media use interactions associated with rich media use, for example, are equal to 1.0 whereas behaviors associated with no use are equal to 0.

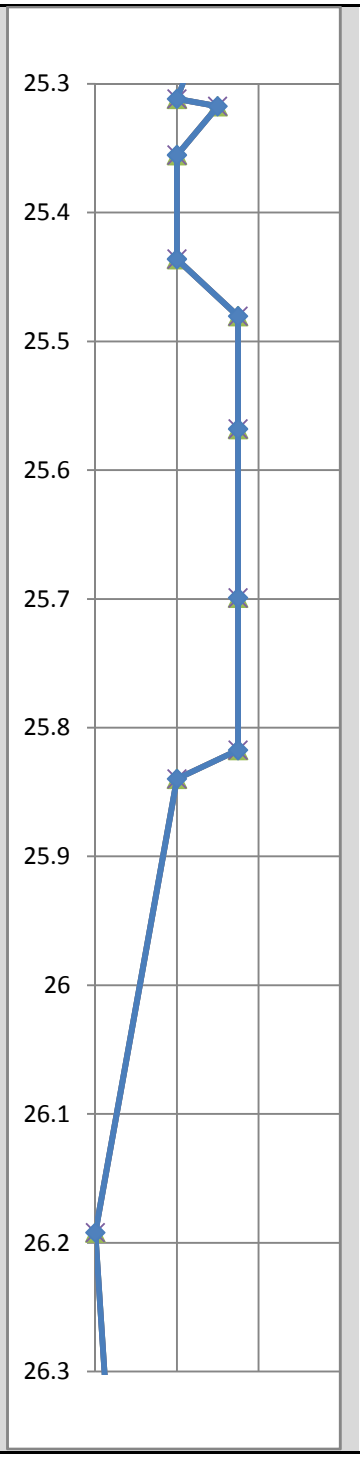
process	no use	low use	medium use	high use	rich use
value	**0**	**.25**	**.5**	**.75**	**1.0**
purpose	no use	learning	communicating	coordinating	performing
interactivity		engaging	directing	annotating	changing
use		supporting		integrating	sharing
		utilizing			

Table 5-9: Values and descriptions for Richness of Media Use Spectrum Zones

Zones	Value	Characteristics
no use	$RMU_n = 0$	team uses no media
low media use	$0 < RMU_n \leq 1$	team views private or semi-shared media to describe
medium media use	$1 < RMU_n < 2$	team points to semi-shared or shared media to describe and explain
high media use	$2 \leq RMU_n < 3$	team annotates shared media to explain or generate
rich media use	$RMU_n = 3$	team uses shared media, changes media content to generate, evaluate, or predict

Table 5-10: Example illustrating values for Richness of Media Use for each segment from a portion of Meeting 80 (Case Example C) shown adjacent to a RMU Sparkline. Richness of Media Use values for segments in Case Example C. The table lists the keyword assignments for the media use MIA codes and the calculated values of the three RMU_n values, MA_n, MI_n, and MP_n. The RMU sparkline shows changes in media use from medium to no use with a majority of the media use in the "medium" use zone.

	Use	Interact.	Access	Purpose	MA_n	MI_n	MP_n	RMU_n	RMU Sparkline
A177: You think the 10' wall is coincident with that wall on the mezzanine catwalk. That's what you are telling me?									
1	digital	viewing	shared	describe	1	0.5	0.25	1.75	
C178: ...that's what the drawing says. Yes.									
2	paper	viewing	semi-public	describe	0.5	0.25	0.5	1.0	
A179: I don't believe that is true. Because you don't have a mezzanine drawing to show me.									
3	paper	viewing	shared	describe	1	0.25	0.5	1.5	
C180: I have a reflected ceiling pattern that says...									
4	paper	viewing	semi-shared	describe	0.5	0.25	0.5	1.0	
A181: but you don't have the catwalk above it									
5	digital	pointing	semi-shared	describe	0.5	0.25	0.5	1.0	
Y182: *((looking at drawing))*									
6	none	none	semi-shared	describe	0.5	0.25	0.5	1.75	
A183: This is perfect.									
7	paper	viewing	shared	describe	1	0.5	0.5	1.75	
A185: Okay. So if that's not true, Can I make 10'5 ceiling coincident with that wall?									
9	paper	viewing	semi-public	generate	0.5	0.25	1	1.75	
C186: Sure.									
10	none	none	semi-public	evaluate	0.5	0.25	1	1.75	
Y187: *((looking at drawings))*									
11	digital	viewing	semi-public	describe	0.5	0.25	0.5	.1.0	
Z188: *((various conversations, looking at drawings, whiteboard)) ((having conversations to work through issues))*									
12	paper	viewing	NA	NA	0	0	0	0	



5.6.1 Findings from the Richness of Media Use Spectra

Richness of Media Use varies more distinctly than Richness of Interaction (Table 5-12). The average RMU value is 1.37 with σ =.78 compared to σ =.18 for RI. RMU ranged from .15 to 2.26. The time spent in the media use zones ranged dramatically as well, with one meeting spending only 1% of the time in the rich media use zone and another meeting 0% of the time in the low media use zone (Figure 5-13).

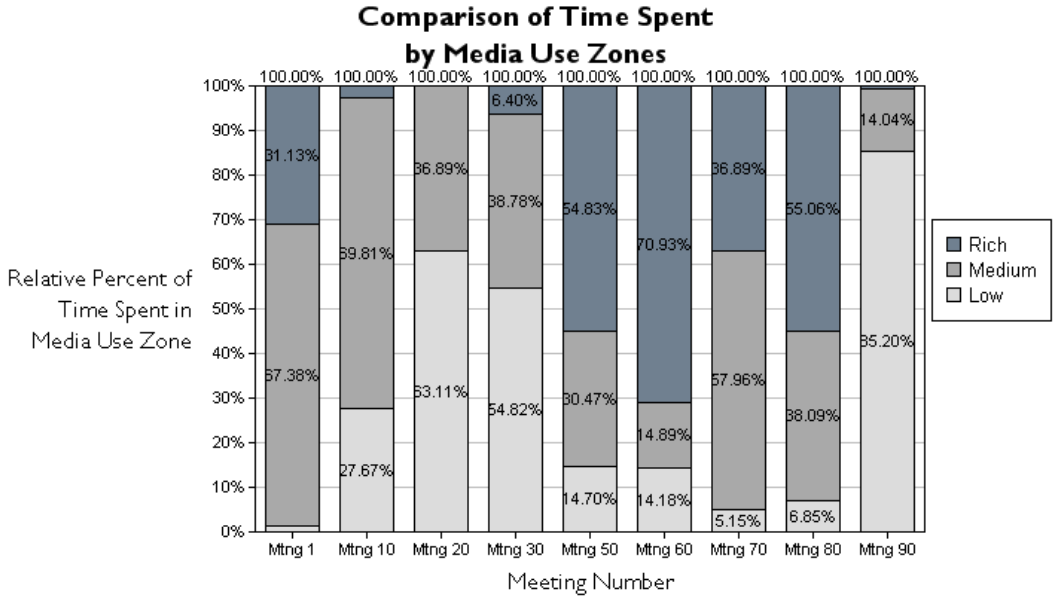


Figure 5-13: Summary of time spent within each zone of the Richness of Media Use spectrum. The data show that how teams use media with respect to time spent in the three RMU zones varied widely across the nine meetings analyzed.

Table 5-11: Summary of Richness of Media Use values for the nine observations including breakdown of time spent in each Richness of Media Use spectrum zone.

	Richness of Media Use: % of Time Spent in Spectra Range			Richness of Media Use
Meeting	Low	Medium	High	
60	14%	15%	71%	2.26
80	7%	38%	55%	2.07
50	16%	30%	55%	1.95
1	2%	67%	31%	1.88
70	5%	58%	37%	1.80
10	28%	70%	3%	1.07
30	55%	39%	6%	0.71
20	64%	37%	0%	0.45
90	89%	11%	1%	0.15
$\bar{x}$	31%	40%	29%	1.37
σ	0.31	0.21	0.27	0.78
minimum	2%	11%	0%	0.15
maximum	89%	70%	71%	2.26

The Richness of Media Use Steplines show distinct differences in how teams use media. For example, the Case Examples illustrate four distinct patterns of media use ranging from no use (Figure 5-14[A]) to constant rich use of media (Figure 5-14[D]). Some teams never move into the high media use zone, whereas others only periodically move into the low *RMU* zone. These patterns of media use recur in meetings. Figure 5-15 shows RMU Steplines for six meetings and describes six patterns of media use. These patterns show that teams do make changes in how they use media throughout the meeting, but in general, the use of media, even if intermittent, shares a similar pattern of use throughout a meeting.

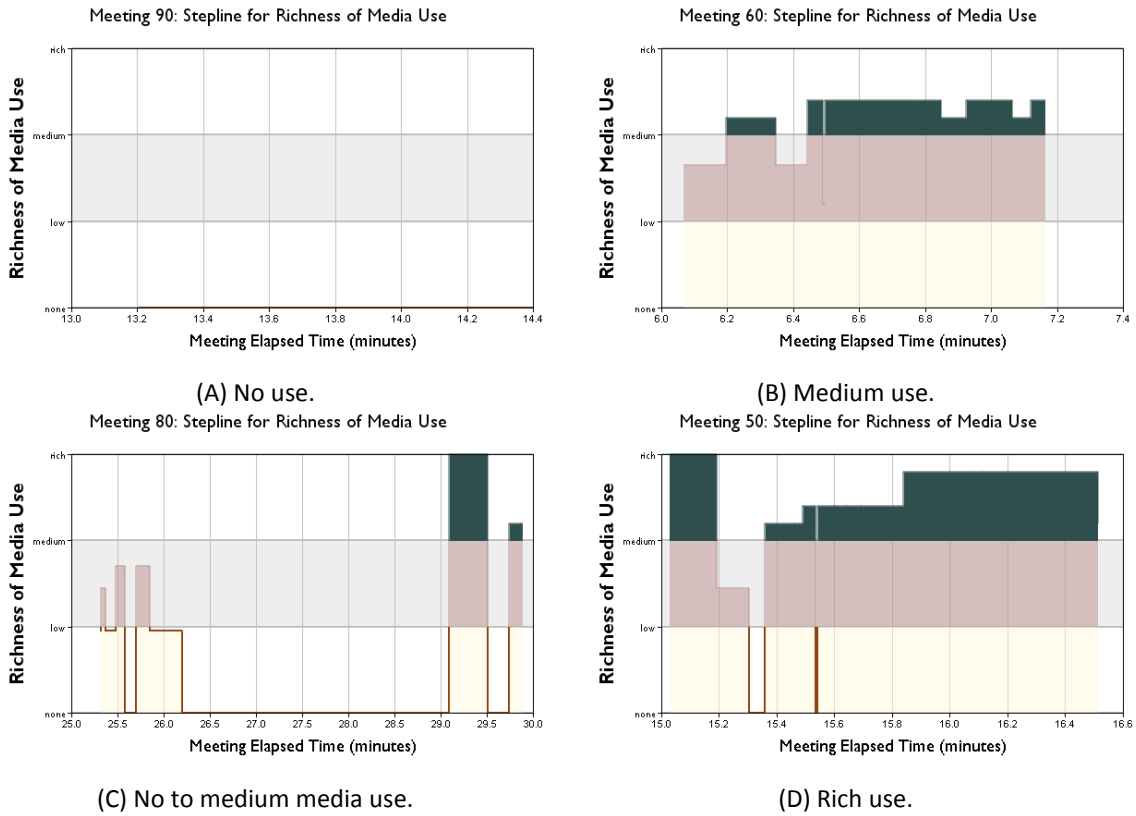


Figure 5-14: Comparison of Media Use Steplines for the four Case Examples. The examples show the wide range of media use from (A) no use, to (C) moderate and intermittent use, to (B) constant, medium use, and to (D) constant, rich use.

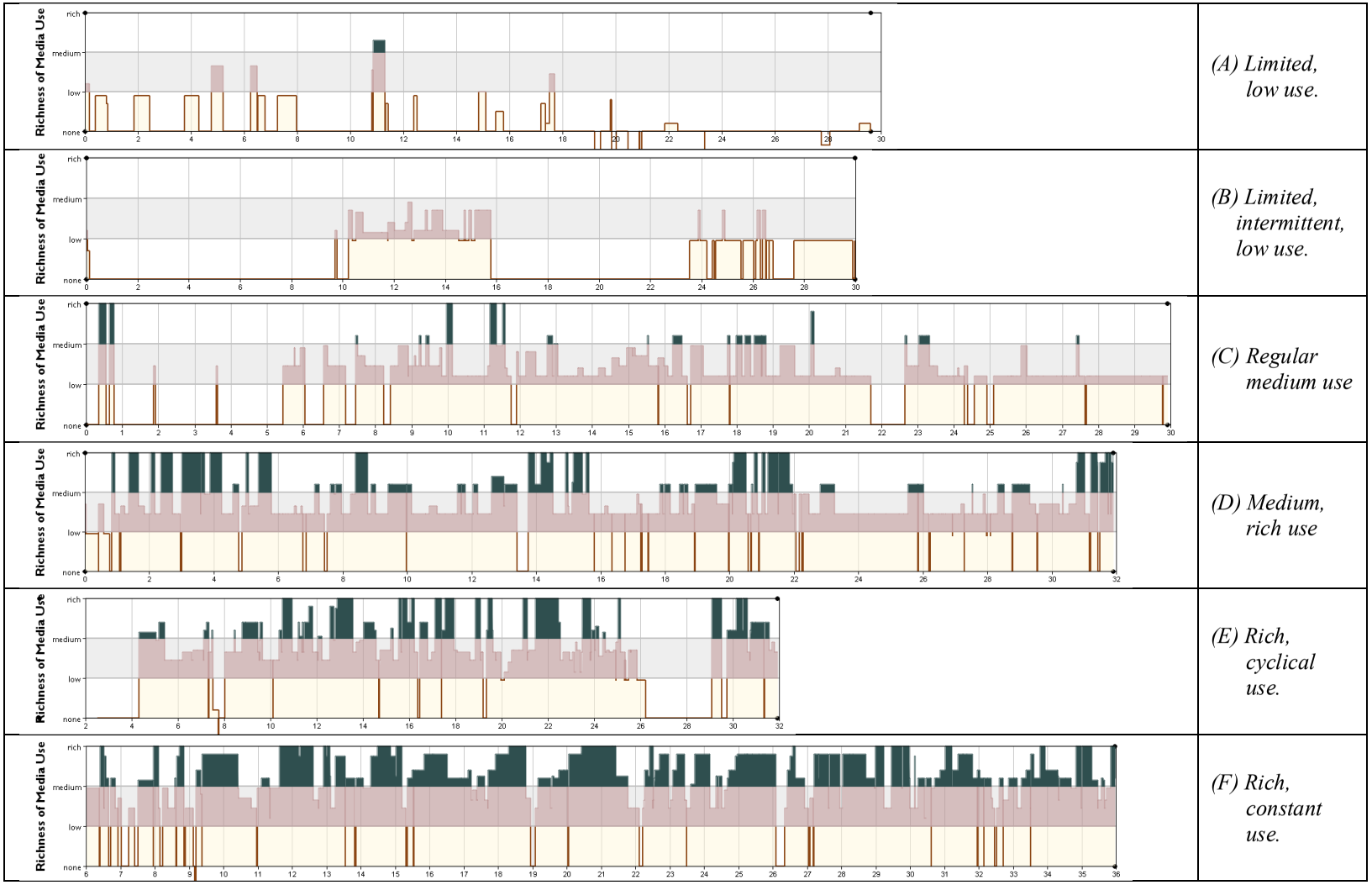


Figure 5-15: Examples of Richness of Media Use Steplines illustrating patterns of media use.

5.7 Comparing Richness of Media Use and Richness of Interaction

Do any of the patterns of media use or interaction relate to one another? Figure 5-16 shows the relationship between the time spent in the RMU and RI zones. Figure 5-17 shows the relationship between the overall RMU value and RI value for each meeting. These figures show that in some meetings there is a trend between RMU and RI, but in other meetings they are negatively correlated. I include these here to show that there is not a clear relationship between media use and team interaction using a comparison of the Richness zones or overall values for RMU and RI for each meeting. There is a need to examine a potential relationship between patterns of media use and team interaction at a finer granularity of analysis for a set of meeting interactions as opposed to the entire set of meeting interactions. I explore this relationship in Chapter 6.

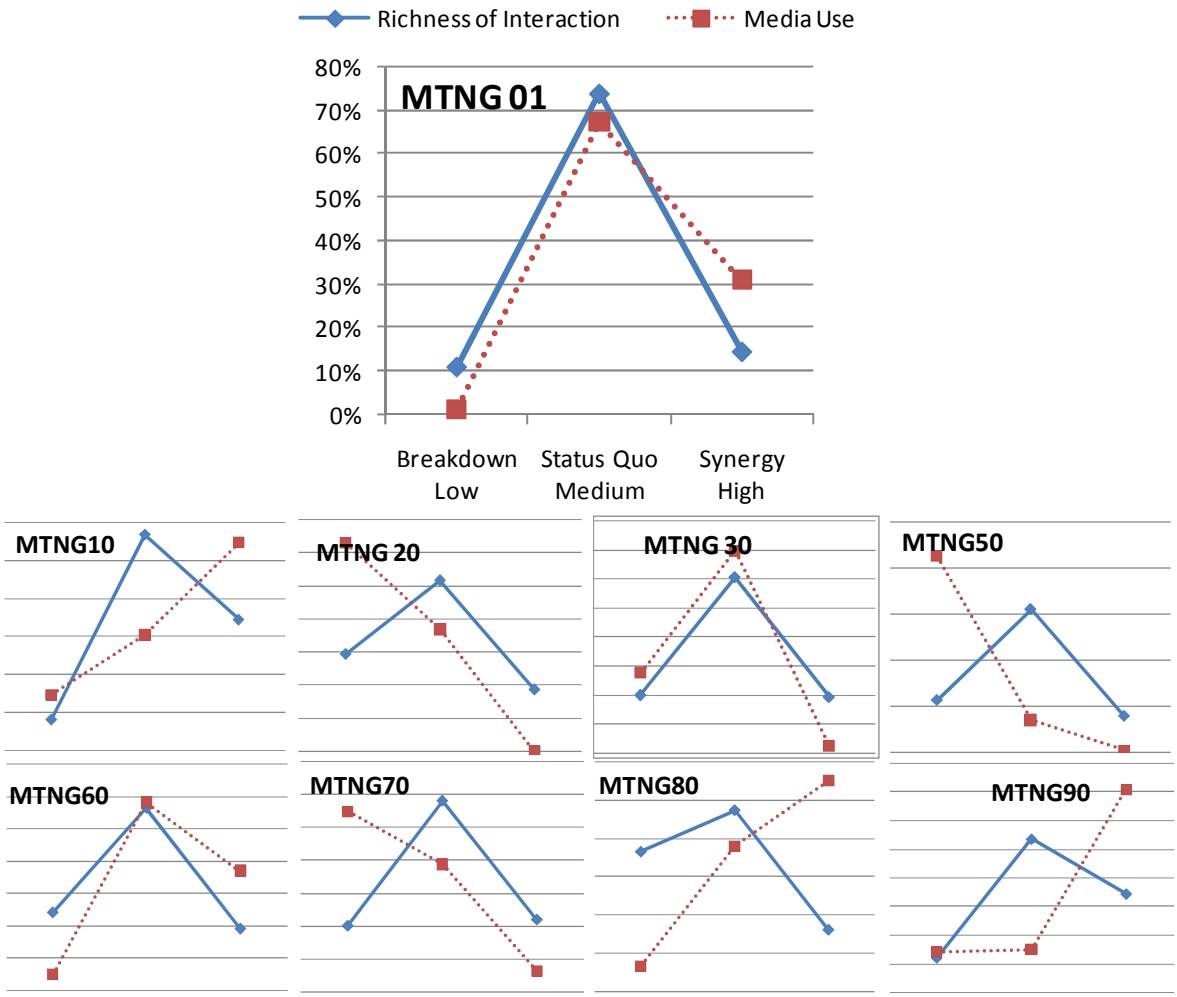


Figure 5-16: Relationship between Richness of Media Use and Richness of Interaction Zones. This shows that for some meetings the media use and interaction are closely related (1, 10, 30, 70, 90), whereas other meetings have no relationship between media use and interaction (20 and 80), and two have a positive relationship between rich use and synergy (60 and 50).

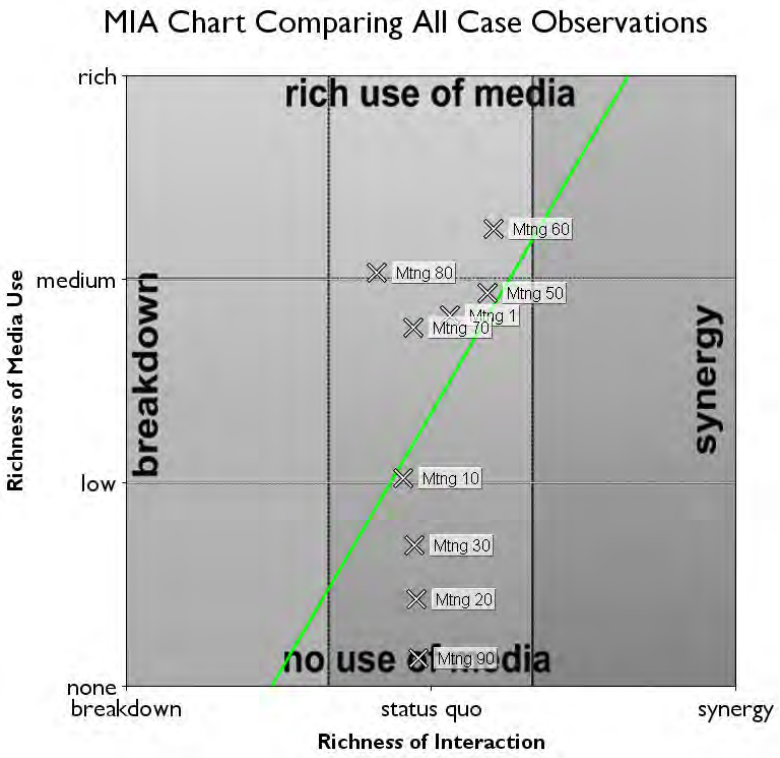


Figure 5-17: Comparison of the static Richness of Interaction and Richness of Media Use values for all nine meetings. This shows a slight trend between Richness of Interaction and Richness of Media use. More meetings that are closer to the synergy zone have high media use. It also shows that variability in media use is far more significant than differences in interaction based on the constructs analyzed.

5.8 Discussion

I claim the Richness of Interaction and Media Use Spectra as a contribution to AEC research based on its effectiveness to describe and compare differences in how teams interact and how teams use media. Prior constructs for team interaction are idealistic and dependent on measuring inputs, such as the type of task or goals, or outputs, such as a tangible artifact, satisfaction, or other outcome. The Richness of Interaction construct is realistic and reflects the range of team interaction observed. As such, it offers practitioners, media designers, and researchers a means to assess the meeting process relative to the status quo or typical interaction. It also offers a means to examine more closely aspects of the meeting process relative to the three zones of interaction. Constructs such as productivity, effectiveness, etc. examine only one aspect of team interaction, typically at one level of analysis, e.g., at the project or process level, and do not capture how these constructs change over time within the process. The Richness of Interaction spectra includes aspects of interaction that relate to the project ("describing", "explaining", "exchanging", "acting" and "producing"), the meeting process("coordinating" and "structuring"), and to the interpersonal interactions ("exchanging", "initiating", "responding", and "expressing").

The findings suggest that when examining interaction relative to synergy, status quo, and breakdowns, it is unrealistic to expect teams to be 100% synergistic, but it is realistic to expect teams to spend 30% of the time in synergy or to avoid breakdowns. Is it realistic to expect teams to spend 50% in synergy? Or is synergy only achievable through time spent in the breakdown and status quo zone? These are questions that the spectra provoke and reframe the questions that researchers and practitioners should pose with respect to team interaction.

Existing models and constructs of team interaction focus on measuring outcomes when the process itself reveals more insights and potential to improve meeting practice and meeting media. The satisfaction data tell us nothing about why the teams were more satisfied or what aspects of media use or team interaction relate contributed to the participant's satisfaction with the process or meeting outcome. The results show that the teams that experienced more synergy were satisfied. Were they productive? Effective? These constructs are difficult, at best, to operationalize for meeting practice and only examine the action aspect of team interaction at either the project or the process level. I argue that the question to ask is whether the team was synergistic. And how often? The Richness of Interaction spectra provoke additional questions, such as: Are breakdowns a necessary aspect of interaction that contributes to synergy? Furthermore, we should expect, as our understanding of meeting practice and the characteristics of that process improve, that the status quo, as I define it, will be re-calibrated or that the threshold for the synergy zone will change.

Similarly, the Richness of Media use construct offers a means to examine simultaneously multiple aspects of media use in multiple media environments. RMU operationalizes one of the fundamental assumptions in MIM: it is not the media that matters but how teams use media that matters. It examines media of different types equally and focuses on the use, interactivity, and instrumental purpose of the media. As such, it shows the extent to which teams engage with and interact with media and accounts for the physical aspect of that interaction. The findings show that meetings vary considerably in the extent to which media use plays a role in the meeting interaction. Some teams relegate media use to the sideline, rarely using media, and only to support discussions. Some teams enact multiple roles for media to communicate, coordinate the process, and produce, and these roles are not a function of media type or meeting environment. This suggests that aspects of team interaction influence the media use process.

There are several limitations to the Richness Spectra constructs and their operational definitions:

(a) RI does not differentiate contributions as a function of when they occur in the meeting, late or early, or in relation to other behaviors.

(b) RI does not account for differences in participation or the effect of dominance on team interaction.

(c) RI assumes that contributions from any type of similar behavior is equal. That is, the operational definition for RI assigns an equal value to all responses and initiations, giving only additional weight to an initiation that introduces a new project issue.

(d) RMU does not account for different types of transitions. RMU only describes these as a function of changes in accessibility or changes in media utilization.

The operationalization of these constructs and their application to nine meetings is evidence for the generality and power of these methods. Furthermore, by operationalizing the model of team interaction and applying it to meeting interaction I provide further evidence for MIM to study the relationship between team interaction and media use. The Richness of Interaction spectra visualize the meeting process from two distinct perspectives of analysis, but do not fully operationalize MIM. Chapter 6 uses the Richness spectra to examine the relationship between how teams behave and how teams use media.

Chapter 6: Patterns of Mediated interaction

> *"In short, no pattern is an isolated entity. Each pattern can exist in the world, only to the extent that is supported by other patterns: the larger patterns in which it is embedded, the patterns of the same size that surround it, and the smaller patterns are embedded in it."*
> (Alexander 1977, p. xiii)

The relationship between team interaction and media use is complex and dynamic. The Richness of Interaction and Richness of Media Use spectra visualizations describe the dynamics of meeting interaction from a single analytic perspective, but are inadequate to describe the relationship between those perspectives, particularly for an entire meeting process. This chapter addresses these shortcomings by answering the following research question:

(RQ4) How can the meeting process be visualized to describe and analyze the relationship between how teams interact and how teams use media?

I answer this question in two parts. First, I develop a Mediated Interaction Analysis (MIA) diagram that orthogonally relates the Richness of Interaction and Richness of Media use spectra to visualize the dynamic between how teams are using media and the interaction. I use these MIA diagrams to describe and compare patterns of mediated interaction in AEC project meetings and explore the role of media use in team interaction. These diagrams are messy and describe the complex relationship between media use and team interaction. The diagrams also show the symbiotic relationship between team interaction and media use. Teams balance the processes of team interaction and media use. The teams that richly used media and balanced the media use process with periods of "coordinating" and "expressing" achieved synergy more often than other teams. These findings suggest that the teams that make media part of the team and engage with and use media in all aspects of team interaction are more synergistic and satisfied. Whereas teams that designate media to the sideline and limit its role experience more breakdowns or simply maintain the status quo. I use these patterns of mediated interaction and draw upon my observations to generate a set of recommendations and discussions related to the findings from applying this approach to AEC project meetings.

6.1 Motivation

Existing methods to compare analytic perspectives pose several challenges. First, side-by-side comparisons such as those in Figure 6-1 require the reader to identify any relationships or trends between the two perspectives represented by the Richness of Media Use Spectra (top) and the Richness of Interaction (bottom). Overlay methods such as those in Figures 6-2 and 6-3 make it easier to identify relationships for small sets of data but more difficult for larger sets of data. For example, Figure 6-2 shows overlays of Richness of Media Use spectra on the Richness of Interaction spectra for each Case Example.

Both spectra have three interaction zones, so they share the same banding and spectrum segmentation. One could interpret a potential relationship between how teams use media and how teams interact since the two spectrum lines generally fall within the same interaction zone and generally trend together. The RMU and RI lines for Case Example A are in the lower zone, and the RMU and RI zones for Case Example B are in the upper zone. The RMU and RI lines for Case Examples C and D move across the zones together. The relationship, if any, is more difficult to discern for longer time frames. For example, Figure 6-3 shows the RMU and RI spectra for a thirty-minute portion for two meetings. It is difficult to identify or describe the relationship using this method. There is a need for a method to describe the relationship between two distinct analytic perspectives that is sufficient for short and longer time frames.

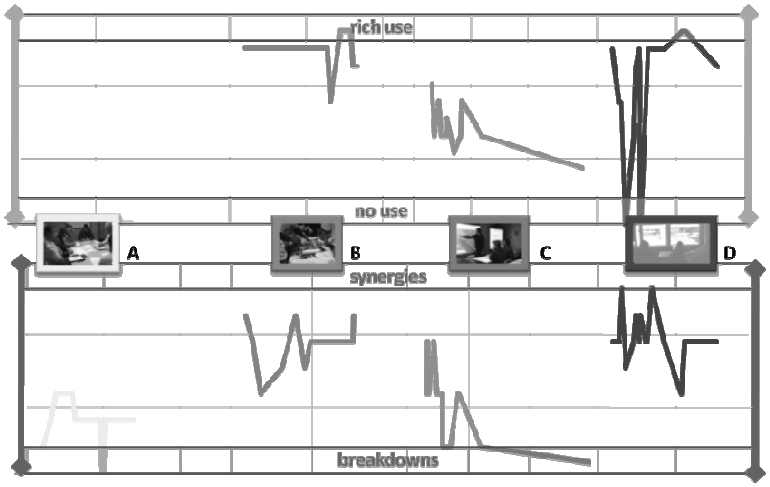


Figure 6-1: Comparison of Richness of Media Use and Richness of Interaction for the Case Examples. The relationship between the two spectra is difficult to interpret.

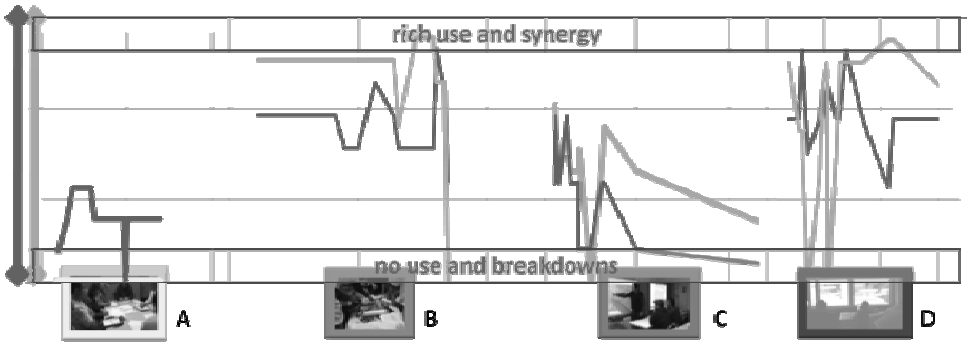


Figure 6-2: Comparison of Richness of Media Use (lighter line) and Richness of Interaction (darker line) spectra. In some cases, the relationship between the two processes is obvious such as in Example C. In other cases, the relationship is less obvious.

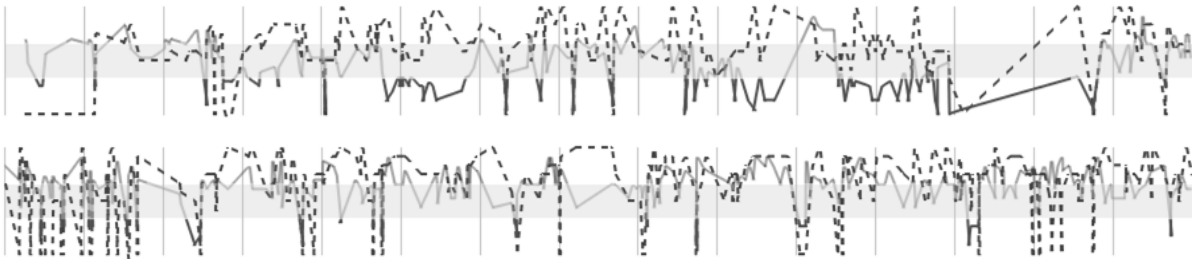


Figure 6-3: Comparison of Richness of Media Use (hashed line) and Richness of Interaction spectra for a thirty-minute portion of two meetings. The figures overlay the spectra since both use three zones of interaction. The relationship between the two processes is more difficult to discern.

6.2 Mediated Interaction Analysis Diagrams

I developed a Mediated Interaction diagram that orthogonally relates the two MIA spectra and forms a visual framework to describe the relationship between how teams interact and how teams use media. Figure 6-4 illustrates the features of the Mediated Interaction Analysis diagrams. Figure 6-4 demonstrates the relational spectra method and visualization features of the MIA diagrams using the RI and RMU spectra. Figure 6-4(A) shows a mediated interaction diagram (MIA diagrams) that uses the RI spectrum for the horizontal axis and the RMU spectrum for the vertical axis. The MIA charting method plots each interaction, i_n, within this matrix diagram using the value for the respective spectrum (RI and RMU) and sequentially connects the points with an *interaction line*. The result is an *interaction profile* that describes how meeting interaction changes moment-to-moment from the two analytic perspectives. Each MIA spectrum has three interaction zones, so the resulting relational spectrum diagram has nine interaction zones (Figure 6-4[B]). The diagram in Figure 6-4[B] simplifies the visualization method by removing the axis labels. One of the shortcomings of the basic relational spectra visualization method is that it does not capture the temporal aspect of interaction (only its sequential nature). To address this shortcoming, some of the mediated interaction diagrams have bubble annotations and labels such as those shown in Figure 6-7. These annotations communicate the time spent in each zone and act as a guide to compare patterns by time spent in each interaction zone.

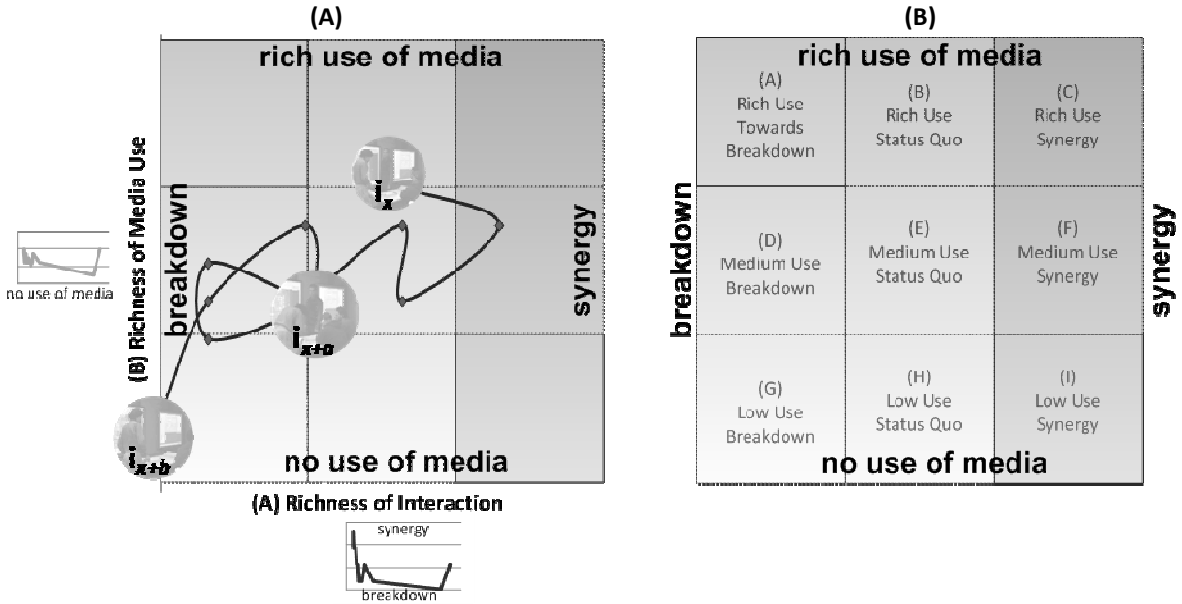


Figure 6-4: Example of a mediated interaction diagram demonstrating the relational spectra visualization method. (A) The mediated interaction diagram relates the Richness of Interaction spectrum (horizontal axis) to the Richness of Media use spectrum (vertical axis). Each meeting interaction translates to an X-Y coordinate using the RI and RMU values. (B) The mediated interaction diagram consists of nine interaction zones that describe differences in how teams interaction and how teams use media.

Figure 6-5 illustrates characteristics of patterns of mediated interaction. These characteristics describe how to use MIA diagrams to describe and compare patterns of mediated interaction and explore the relationship between media use and team interaction:

a) *Flow* across mediated interaction zones. The example in Figure 6-4 starts in (B), moves to (F), then (E), (D) and ends in (G). This flow analysis supports analysis of the relationship between changes in media use and team interaction. These flows are also describable in terms of their direction, towards breakdown or toward synergy (Figure 6-6[B] and [C]) or towards rich use or low media use (Figure 6-6[E] and [D]). Identifying common flow patterns and analyzing aspects of the interaction may lead to a relationship between aspects of media use and team interaction. Are there more ideal flows or sequences of mediated interaction associated with synergy? Breakdowns? Status quo?

b) The flow is describable in terms of its *profile* or shape. Some interaction profiles produce regular shapes while others are messy. For example, there are linear patterns (Figure 6-5), inert patterns that move within one mediated interaction zone, cyclical, and irregular patterns. For example, the profile in Figure 6-4 is irregular. This dimension of analysis explores the relationship between ad hoc and structured mediated interaction. Are linear or cyclical patterns ideal? What is more common?

c) *Range* of interaction in terms of its coverage across the mediated interaction zones. Interaction may be limited to one zone, span several zones, or all zones. Differences in interaction are describable in terms of where interaction occurs and where interaction does not occur. What is a normal range of mediated interaction? Is a wide range associated with synergy?

d) *Regularity* of interaction as shown by the density of the interaction profile line. If the team repeats the same mediated interaction patterns, the profile is denser within certain interaction zones. Is regularity associated with synergy or status quo, or both?

e) *Line of mediated interaction balance* as shown by the line in Figure 6-5(A). The line of mediated interaction balance is a trendline for all the RMU and RI values for the analyzed interaction. The slope and direction of this line reflect the balance of media use and team interaction. Do synergistic teams balance media use and team interaction?

I use these characteristics to describe patterns of mediated interaction. There are potentially multiple ways that a researcher can use the relational spectra method to describe and compare interaction. The following sections discuss the findings from applying this method to the Case Examples and nine AEC project meetings.

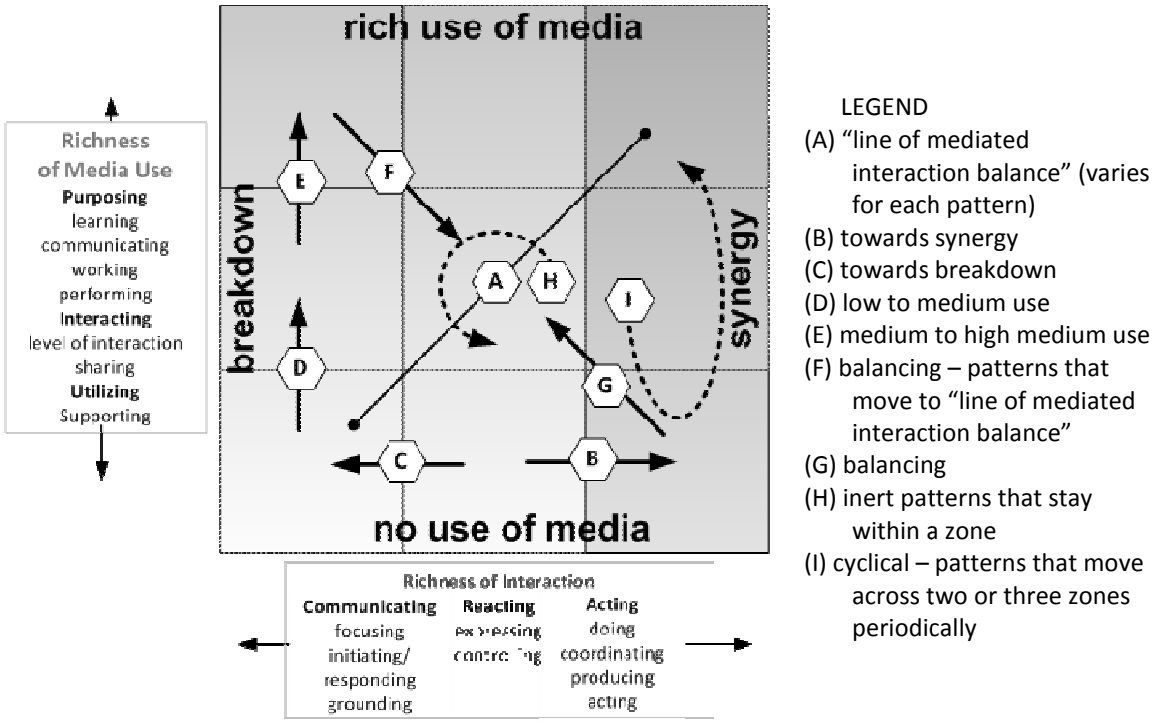


Figure 6-5: Characteristics of patterns of mediated interaction. The diagram shows characteristics of patterns of mediated interaction that are useful to describe and compare patterns of mediated interaction.

6.3 Using MIA Diagrams to Compare the Case Examples

Figure 6-7 shows MIA diagrams for the four Case Examples. The diagrams show the differences in how the teams interacted and how the teams used media. The two synergistic patterns, B and D, are cyclical and regular patterns of mediated interaction. Example B moves within a smaller range of mediated interaction than Example D. Team B uses the media continuously as they generate ideas. Team D balances media use with periods of social interaction. Both teams have a media and process facilitator. While Team B uses a paper-based media environment and Team D uses a digital-based media environment, both interact and engage with the media in all aspects of team interaction at all levels of interaction. The teams

use shared media and assign different functions to the various media. They structure and coordinate their activities using the media. The patterns of mediated interaction capture this to some extent with the cyclical, regular patterns and through the flow of the activity that is predominantly in the rich use and in the synergy zones.

The patterns of mediated interaction for Examples A and C tell a different story. Example A is an inert flatline (Figure 6-6[A]). The team uses no media and limits the range of interaction close to the status quo zone. The regularity of the interaction, though, captures the structured nature of the interaction, but this does not result in action. The team uses an agenda to structure the interaction, but repeats the pattern shown in Figure 6-7 of communicating issues but failing to close the loop on the communication. The pattern of mediated interaction in Team C is a breakdown pattern. These are rare, but start with a breakdown in communication. In this case, the breakdown occurs as the team transitions between media. The team divides their attention between shared media and semi-shared media. Rather than using media to coordinate their activity, the media use divides the team activity. One participant prefers the drawings as a medium to communicate design information and the other meeting participant prefers the shared digital model. The team moves from status quo and medium use to a breakdown and no media use as the participants become frustrated and stop communicating and working together.

The line of mediated interaction balance for these examples abstract these patterns and offer a quick glimpse of the relationship between media use and team interaction. Media use plays no role in the team interaction in Example A. The line of mediated interaction balance for Teams C and D that have similar media environments differ in the range. Team D balances media use at all levels of interaction, whereas Team C does not move beyond the status quo. Team A balances media use within the synergy zone of team interaction.

6.4 Patterns of Mediated interaction

These patterns of mediated interaction are not isolated patterns and are best examined in relation to the overall patterns of meeting interaction for the meeting process and in relation to other patterns of mediated interaction that occur in the meeting. Figure 6-10 and Appendix O includes examples of various patterns of mediated interaction for each meeting I analyzed. Each example includes three patterns of mediated interaction observed in each meeting with a description of the pattern using the characteristics discussed in the previous section and illustrated in Figure 6-5.I refer to these in the following sections as I discuss the findings and what I learned, particularly with respect to how these patterns unfold within the meetings.

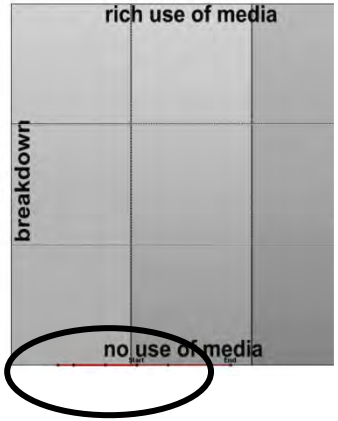
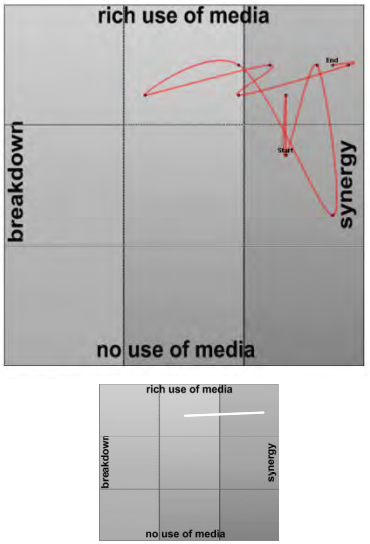
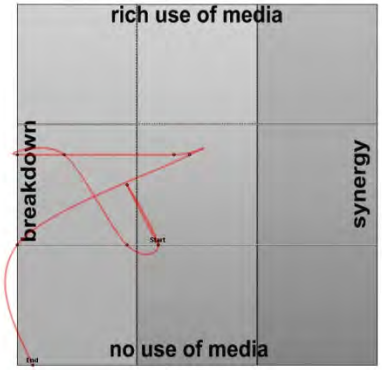
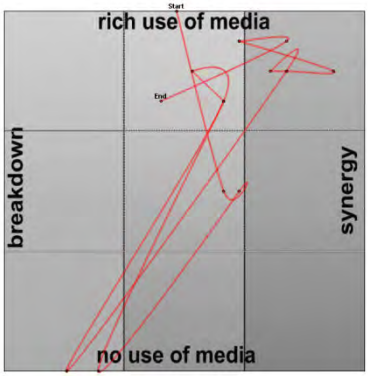
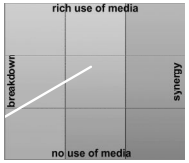
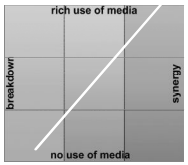
	Case Example A: Flatline, Maintaining Status Quo	Case Example B: Cyclical Synergy and Rich Media Use	Case Example C: Breakdown	Case Example D: Balanced Synergy
				
				
Flow	G→H→I	C→F→B	E→D→G	B→C→G
Profile	Linear, inert	Cyclical	Irregular	Cyclical
Range	3 zones	3 zones	3 zones	4 zones
Regularity	Yes.	Yes.	No.	Yes.
Line of Mediated Interaction Balance	Low, Flat	High, towards rich use and synergy	Unbalanced	Balanced
	The team tries to address and clarify an issue relying on individual expertise. The team uses no media and does not "close the loop" on the issue.	The team works together and coordinates their activities with media. The team uses the media as a workspace to generate ideas and as a coordination device. Two participants act as media facilitators	The team moves between public media and semi-shared media as they try to resolve a problem. The team fails to agree on an issue, stops communicating, react negatively towards one another, and fail to address the problem.	The team identifies an issue, uses media to solve the issue, document the solution, and balances this process with social interaction.

Figure 6-6: Comparison of mediated interaction for the four Case Examples. The MIA diagrams describe differences in the relationship between how teams used media and how teams interacted.

6.5 Findings from Using MIA Diagrams

The findings show that patterns of mediated interaction are not a function of the media environment or the type of meeting and the patterns of mediated established early recur throughout the meeting. Figure 6-9 compares the nine analyzed meetings in relation to the type of media environment and the phase during which the meeting took place. Although two of the paper-based meetings do not show any activity in the rich media use zones, one of the paper-based meetings shows rich media use and synergy. Similarly, the mixed-media use meetings show a range of patterns of mediated interaction. The type of media is less important than how the team uses the media.

Significant findings from using the MIA diagrams include:

- There is a natural balancing of media use and team interaction as evident from the minimal activity in MIA zone (A) and (I). Teams rarely use media richly for extended periods of time and either move towards status quo and synergy or move towards less rich media use. Likewise, there are few extended periods of synergy that involve no or low media use. This suggests media use plays a role in synergy.
- Patterns of mediated interaction vary widely in the range of interaction with some predominantly inert patterns of interaction, characterized by more than 40% of the time in one mediated interaction zone (Meetings 1, 10, 60, and 90) and all teams spending at least 25% of the time in one mediated interaction zone. Some meetings had interaction limited predominantly to only 3 zones such as Meeting 20 and 90, which are both paper-based. This suggests teams establish patterns of mediated interaction and do not vary those patterns within a meeting.
- The synergistic meetings, Meetings 50 and 60, spent a majority of their time in MIA zones (B) and (C) whereas the status quo meetings spent a majority of the time in MIA zones (E) and (H). This suggests a mutual relationship between media use and team interaction.
- Regular cyclical patterns that include the rich use and synergy zones correlate with satisfied teams. For example, the teams in meetings 60 and 50 were satisfied with the process and outcome of their meetings and the MIA diagrams show the clustering of activity in the synergistic and rich media use zones. The diagrams provide an overall general description of the relationship between team interaction and media use in a richer way than previous methods that use single constructs or set of operational measures.

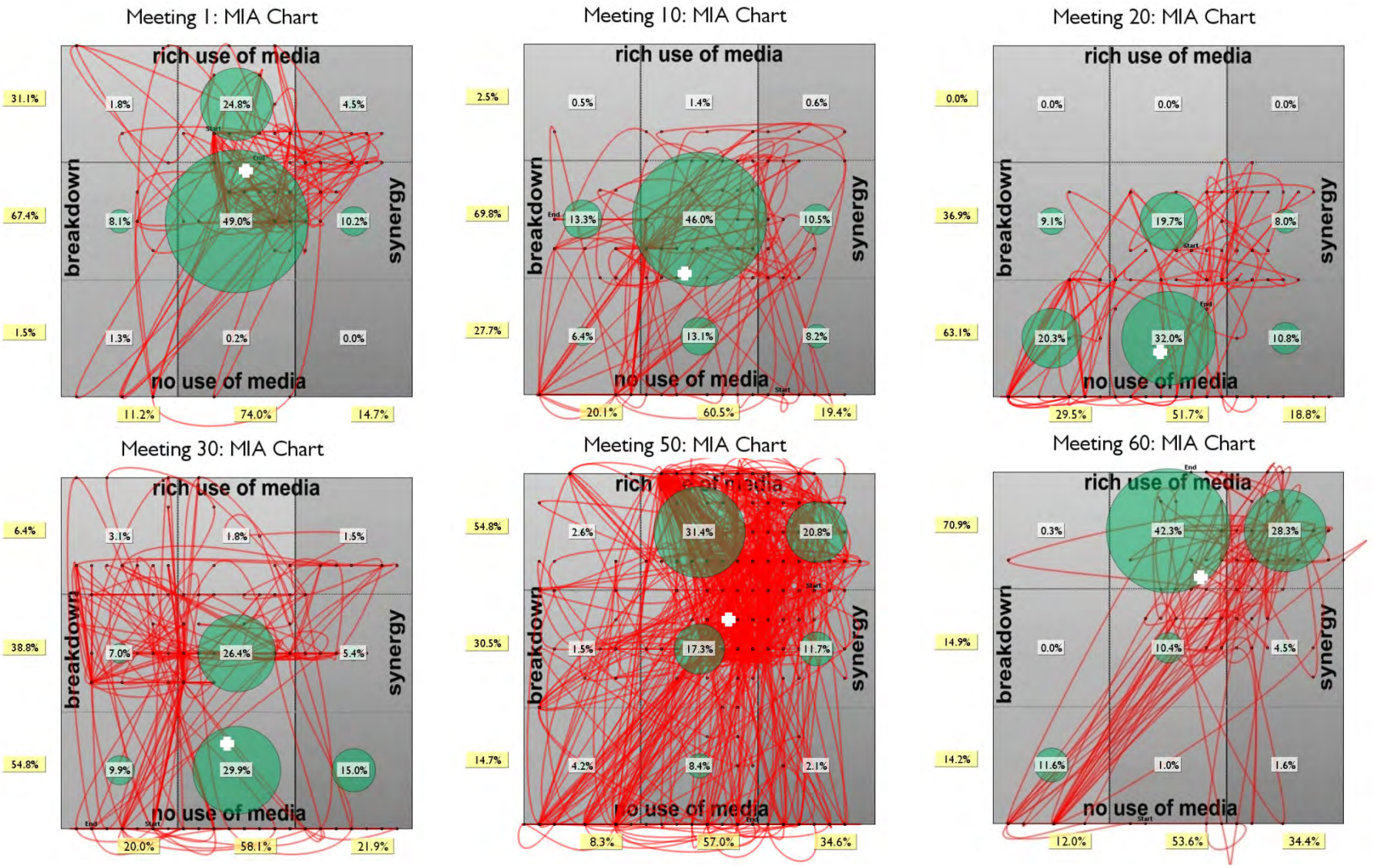


Figure 6-7: MIA diagrams for six of nine AEC project meetings analyzed in this research. These diagrams show the wide range of mediated interaction.

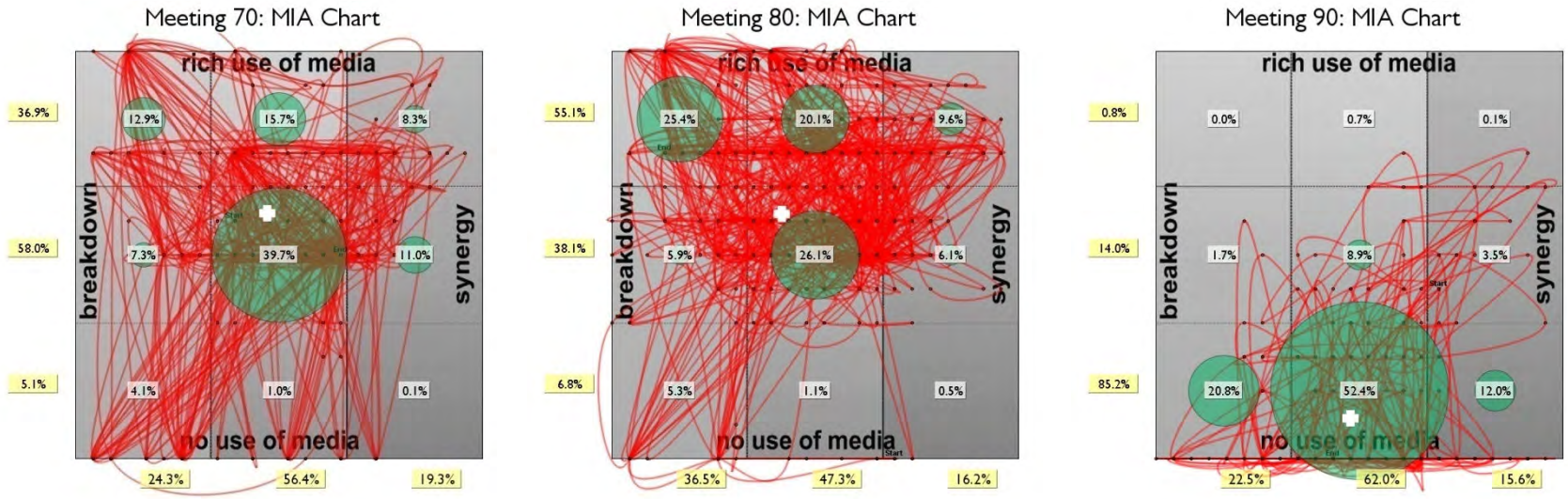
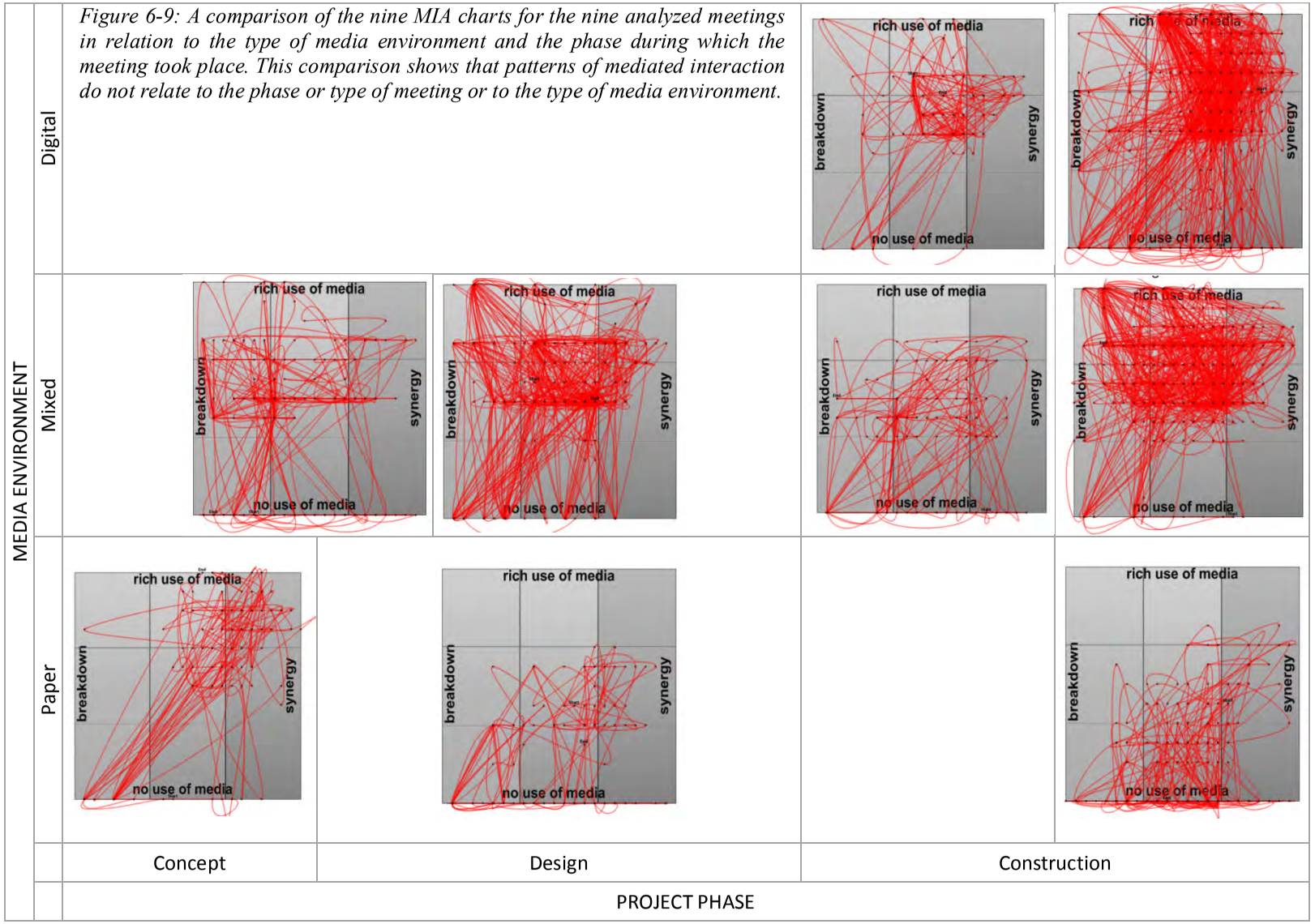
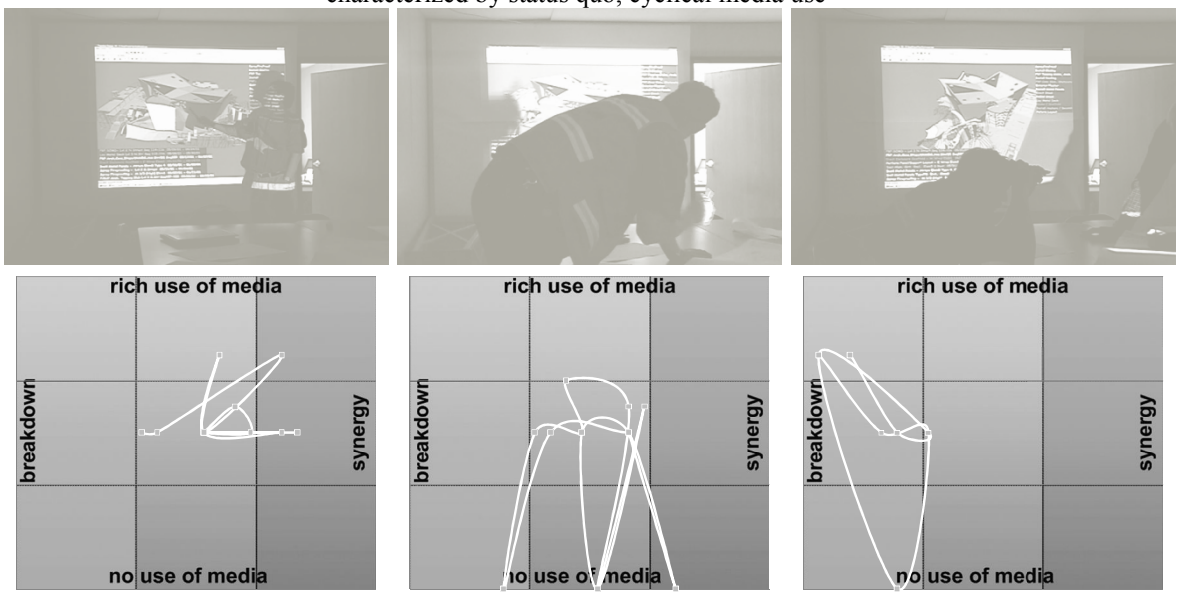


Figure 6-8: MIA diagrams for three of nine AEC project meetings. These diagrams show the wide range of mediated interaction. Meetings 1 and 10 represent status quo-medium use meetings. Some meetings, such as meetings 30 and 50, exhibit a wide range of mediated interaction, whereas other meetings, such as Meetings 1, 10, 20, and 90 exhibit a limited range of mediated interaction. The diagrams also show that teams rarely spend time in the low use-synergy zone (except Meeting 90) or the rich use-breakdown zone. This suggests the mutual balancing process

Figure 6-9: A comparison of the nine MIA charts for the nine analyzed meetings in relation to the type of media environment and the phase during which the meeting took place. This comparison shows that patterns of mediated interaction do not relate to the phase or type of meeting or to the type of media environment.



Meeting 70: Media as Communicator and Backup
characterized by status quo, cyclical media use

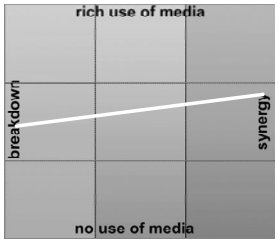


(A) The team lets the media do most of the communication. The team reviews the model, using a media facilitator and media annotator.

(B) This irregular pattern moving between medium and low use involves a series of questions that the team must rely on information not communicated by the media.

(C) Several periods during the meeting involve transitions from the shared, digital media to semi-shared paper media on the table. This results in team interaction that falls below the status quo.

The team uses shared media to communicate, mixing semi-shared media with private and shared media. The team repeats this pattern using a media facilitator and using the media to structure the meeting process.



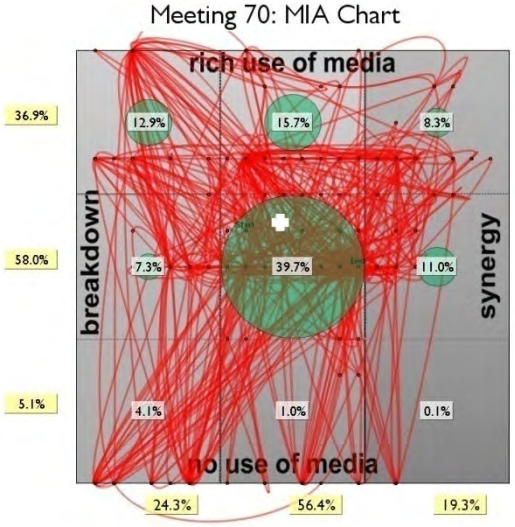


Figure 6-10: Example of patterns of mediated interaction from a single project meeting. Meeting 70: Media as Communicator and Backup characterized by Status quo, cyclical media use
Media as communicator

6.6 Discussion and Recommendations for Practitioners and Researchers

How can these patterns of mediated interaction and findings from MIA improve media design and meeting practice? The following sections summarize recommendations for practitioners and media designers and researchers that draw upon the patterns of mediated interaction (see Appendix O) as resources and findings from using the MIA approach. The discussion draws upon the patterns of mediated interaction and the overall MIA approach, including the observations, interaction analysis, development, and analysis of the Richness Spectra.

6.6.1 Practitioners

The teams that achieved synergy also made media part of their team, i.e., media played a role in key aspects of team interaction, from communication to reaction to action and from breakdowns to synergies. These teams facilitated and structured both the process and the media use. The following are recommendations for practitioners with respect to selecting and setting up the media environment:

Make media accessible.

Without access to media, teams cannot collectively communicate. Differences in "accessing" are associated with different patterns of mediated interaction. These differences in "access" stem in part from differences in the physical layout of the meeting media environment. Figure 6-11 compares the layout of each of the meetings. Meetings 10, 20, 30, 60, 70, and 90 are examples of a typical conference meeting space. The conference-table layout typically inhibits shared media use since media on the table is not accessible to all participants and participants often use private or single media (Meetings 20 and 90 are examples of this). Private media, such as handouts, often act as a distraction and take focus away from the meeting interaction. For example, the pattern of mediated interaction in Case Example A (Figure 6-6[a]) illustrates the lack of synergy that occurs when teams use media that is inaccessible. Meetings 20 and 90 exhibit patterns of low/status quo media use (Figures 6-8 and 6-9). In both cases, the teams have copies of documents in front of them that divide the teams' attention between each other and the private media. In Meeting 60, though, the size of the team, seven participants, is appropriate for sharing media in a conference table layout. Several of the team participants stand throughout the meeting so all team members can participate in the use of the media. As a result, Meeting 60 exhibits a synergy/rich media use pattern of mediated interaction. Meetings 10, 70, and 80 involve the use of shared, semi-shared, private, and single media. These meetings exhibit status quo/medium use or towards breakdown/low use patterns of mediated interaction. The meetings involving predominantly shared media, such as Meetings 1, 50, and 60 spent less time in the breakdown zone. These patterns of mediated interaction suggest that practitioners should consider the overall design of their meeting space and to the extent possible, use shared media.

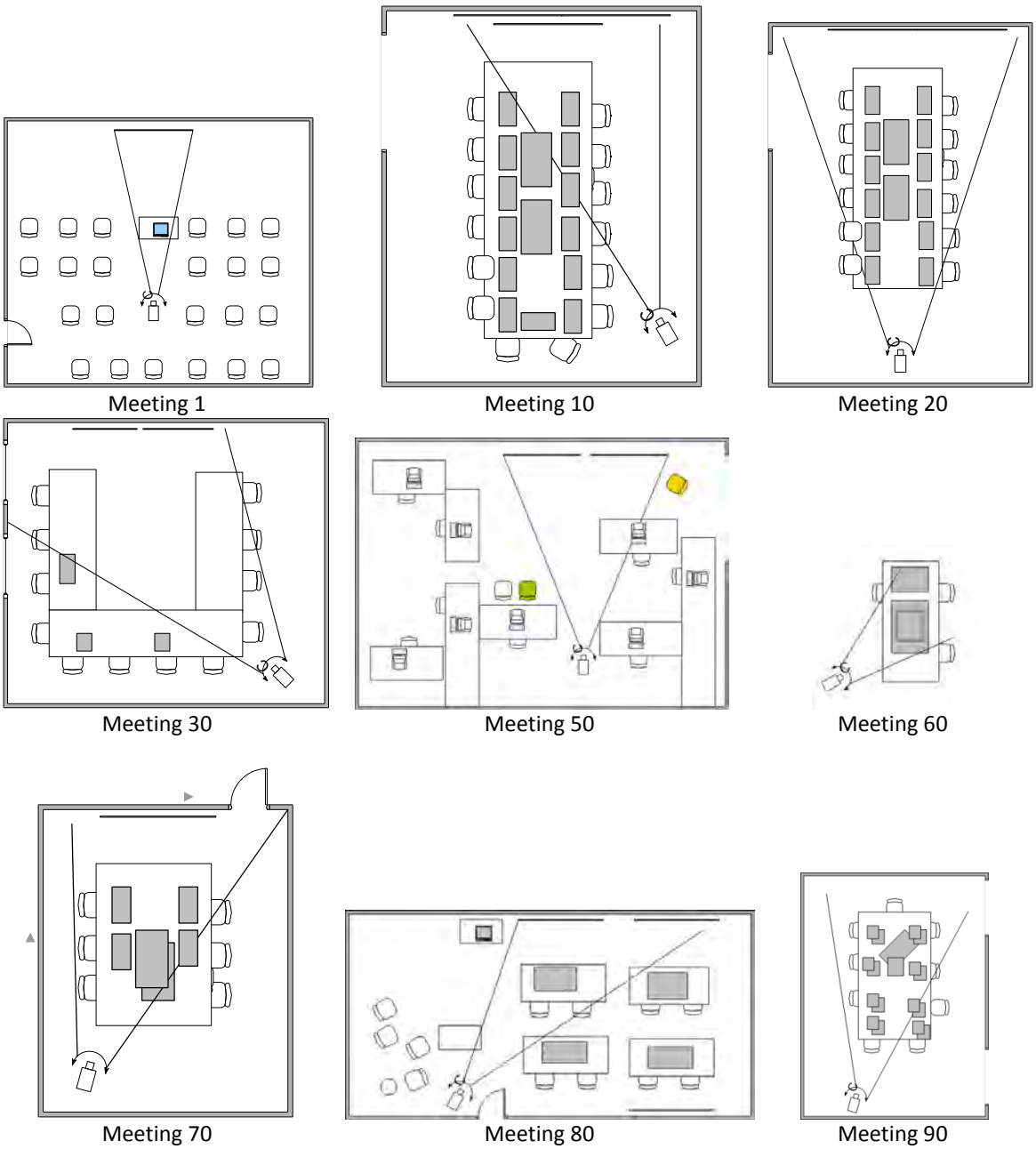


Figure 6-11: Comparison of layout of meeting spaces and location of media in meeting space. Meetings 10, 20, 60, and 90 are examples of typical conference-table meeting space. Meetings 10, 30, and 70 are examples of screen-oriented media environment. Meeting 1 is a screen-oriented media environment with theater-style seating and no workspace for any meeting participants. Meetings 30, 50, and 80 are multi-display meeting environments. The design of the meeting space affects the accessibility of media and level of interactivity with the media.

Encourage use of media – "utilizing".

Encourage use of media, particularly in the exploratory phase of a specific medium, by all or as many participants as possible. Teams cannot use media to support shared communication or action until all meeting participants are familiar with the environment or use of the media. The patterns of mediated

interaction from Meetings 20 (Figure O-2) and 30 (Figure O-3) are examples of media use during the exploratory phase. In Meeting 20, one participant controls the use of the media whereas in Meeting 30 the team encourages use and experimentation. At the end of Meeting 30, the team engages with the media and begins to explore uses of media to support communication and action. In Meeting 20, the team abandons the use of the media when they turn to focus on project issues.

Use (and locate) media that affords a variety of interaction modes – "viewing" to "directing" to "annotating" and "changing".

Media that is static or frozen do not allow for richer levels of interaction such as annotating or changing the media content. These features apply to all forms of media. Some forms of physical media are more difficult to annotate or change, such as physical models or a digital document viewed on a projector. The team can turn the models but easily make changes to the physical form of the model. The team can point to the digital model but cannot change the content or easily annotate the model. In such cases, the features of the media limit the potential for different types of interaction. In general, paper and digital media share similar affordances and interaction modes. Paper media supported "annotating" and "changing" as did digital media. For example, the two meetings exhibiting the richest use of media are a paper (Meeting 60) and a digital meeting (Meeting 50) and these meetings had the highest RI values. These teams used media that supported a variety of interaction modes and located the media to support all types of interactivity by all meeting participants. On the other hand, teams in Meetings 90 and 20 used private paper-based media that did not readily afford annotation or changing since the media was available to only a few participants. This limits or inhibits engagement or ability to move beyond use of the media to support communication and to use the media to support action. These teams had status quo team interaction and low medium use.

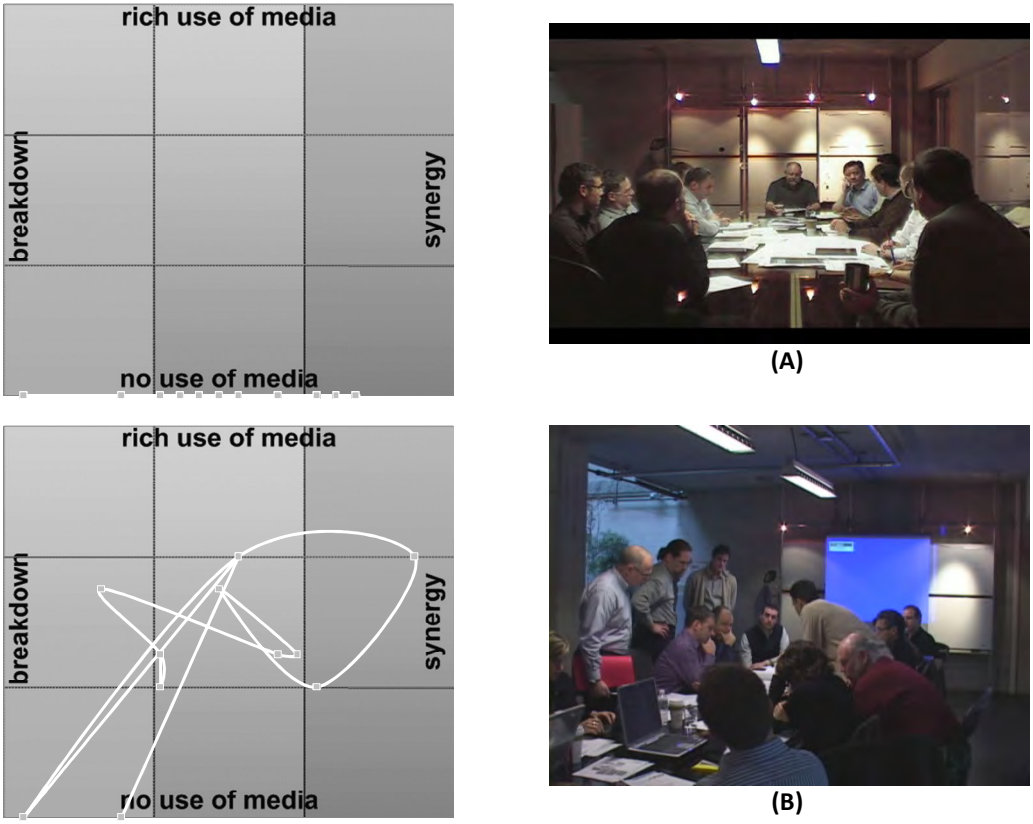


Figure 6-12: Examples of a pattern of mediated interaction that shows the wide range of team interaction when discussing project issues involving a variety of project information unsupported by the media. (A) Shows a pattern of mediated interaction in the no media use zone, moving from the "towards breakdown" to "toward synergy" zone. (B) Shows the use of a single medium that only communicates some of the project information and requires the team to "fill" in the other information, resulting in a wide range of team interaction.

Use media that communicates a variety of project information, "describing" to "explaining" to "coordinating" to "performing".

MIA does not distinguish between different types of media in terms of the information that the media communicate. Instead, MIA examines to what extent the teams use media to support the communication and exchange of project information. In doing so, there are notable gaps in media use when the team relies on their conceptual knowledge of project issues and do not use the media to either support or perform communication. These gaps occur for three reasons. First, the media available in the meeting does not communicate the project information, such as a discussion in Meeting 20 about electrical codes (Figure 6-12[A]). The team uses no media as they discuss this issue and move across the status quo zone to "towards breakdown" and "towards synergy". The team must spend time to clarify these issues relying on the knowledge of one meeting participant. Second, no single media communicates the necessary project information, so the team must transition between different media. For example, in Meeting 30 (Figure 6-12[B]), the team discusses a strategy for scheduling the construction of three buildings and the issues with

respect to underground utilities. To address this issue, the team needs to exchange a variety of project information including electric, schedule, site, and structural. No single medium communicates all this information and, in some cases, no medium communicates the relevant project information. The team spends time discussing the information rather than spending time to transition between the various drawings. Third, the media does not communicate relationships between the information and the team must spend time understanding those relationships.

Although the MIA approach does not analyze each interaction in terms of the project information at this level of detail, i.e., electrical or structural information and the relationships a specific medium communicates, the MIA charts communicates what happens when the media does not support the communication or action needs of the team. When the media does support the communication of project information and the relationships between the project information, these gaps do not occur, such as in Meetings 1, 50, and 60. These teams use media that communicate a variety of project information, such as multi-disciplinary models, construction schedules, and drawings with overlays, and that convey relationships between the project information. Consequently, these teams spent only 11%, 8% and 12%, respectively, in the breakdown zone.

Use media to "produce", "structure", "coordinate", and "express".

The "status quo" teams predominantly use media to communicate whereas the "synergy" teams use media to produce, structure, coordinate, and express. Although different media may support to varying degrees "producing", "coordinating", and "structuring", the observations and MIA charts show a wide range of purposing independent of the type of media. Only meetings 50, 60, and 80 demonstrate teams using media to produce project information and only meeting 50 demonstrates teams using media to coordinate. In Meeting 50, the team used one display to capture issues the team resolved and to use it as a guide to track progress and issues to resolve in the meeting. These meetings exhibit patterns of mediated interaction with predominant activity in the rich use zone and from status quo to synergy zones (Figures 6-8 and 6-9). The teams selected media and setup the media environment to support "producing" by all team participants. In the other meetings, the teams primarily relegated the purpose of media to "communicating". In some cases, such as Meetings 10 and 30, the teams were "learning" features of the media and did not instrumentally purpose the media. In other meetings, the team simply does not use features that support "producing" or "coordinating". For example, in Meeting 1, the team uses a medium to communicate the project schedule, but never uses the media to produce alternative schedules or to coordinate the meeting process. The team adequately responds to issues, but when an issue requires changes to the model, the team defers the issue to a later meeting. In this case, the medium supports "producing", but the team does not use the medium to support this task.

The teams in Meetings 50 and 60 also integrated media into the reaction process, using media to joke and provide positive support. In Meeting 50 (Figure O-F), the media supported positive "expressing" in two ways. First, as the team addressed issues they used the media environment to list the successful images. After addressing a project issue, the team would note this and capture it with the media. Each time, the

team would express positive statements with the successful resolution of an issue and each team member could visualize and share in this success. Second, the team would intermittently play around with the media and this often provided comic relief. Similarly, in Meeting 60, the team used the media to capture ideas and the team members shared in the positive support of those ideas. The team also joked while using the media. In both cases, the media environment, its accessibility, the level of interactivity the media afforded, and the type of information the media communicated, supported positive expression. Even though, the specific media features do not support social interaction, the teams integrated the media use into the reaction process. DeSanctis and Poole (1994) refer to this as "appropriation" or the process of changing the spirit and structure of a media (Chapter 2). Teams appropriate media differently. The MIA charts and analysis suggest that as media use increases, some teams find ways to use media to support and eventually perform a range of meeting tasks. These teams, such as those in Meetings 50 and 60, find ways to combine media and integrate it into key aspects of team interaction.

Use media to "perform".

One of the key differentiators in media use is the extent to which teams use media to "perform". Most teams talk-over media and use the media to support communication of project information. Teams that learn to let the media do the communicating, a characteristic of rich media use, achieve synergy. The teams in Meetings 1, 50, 60, and 80 spent 20%, 31%, 55%, and 25%, respectively "performing" compared to less than 4% for the other meetings (except Meeting 30 where the rich media use is a function of "learning" and exploring features of the media). The team lets the media do the work and gives time for all meeting participants to reflect and focus on the project information.

With respect to **process changes**, practitioners should:

"Coordinate" and "structure" process and media use .

Teams can encourage use of media, but having someone who can facilitate that process is instrumental. The situations where teams either had proficient experience with the media or identified someone as the media manager led to more rich interaction (Meetings 1, 30 (during learning phase), 50, and 60). These teams exhibit patterns of mediated interaction that balance rich media use with synergy or rich media use with status quo team interaction (during the learning phase). These teams spent more time "coordinating" and "structuring" and exhibited more regular patterns of the "coordinating" and "structuring" processes (See Chapter 4). In this sense, MIA captures the informal or formal role of process facilitation in meeting interaction. The meetings with the regular patterns of "coordinating" and "structuring", such as Meetings 50 and 60, exhibit cyclical patterns of mediated interaction between status quo/medium use mediated interaction zones or low use and towards synergy/rich use mediated interaction zones(Figures O[A, B].

Although, each meeting informally had a "coordinator", the regularity of "coordinating" varied widely across the meetings (Chapter 4). The "coordinator" was typically the project superintendent or project manager, and his/her primary role was stating meeting goals ("structuring"), maintaining flow of

meeting, and focusing the team's attention on project issues. One factor that potentially plays a role in the regularity of "coordinating" is whether the meeting also has a "media manager". A "media manager" is fluent and familiar with the various media, the technologies, the layout of the space, and his/her primary role is to encourage and support use of media. Meetings 1, 30, 50, and 60 had a "media manager" separate from the "coordinator". In Meeting 80, the meeting coordinator was also the media manager and this resulted in several near breakdowns, when the meeting coordinator had to focus on the media (Figure 0-8[B]).

Another key difference is how the teams integrated the use of media with the process of coordinating and structuring. The teams that integrated media into the process of "structuring" and "coordinating", e.g., using media to communicate or guide process, exhibited more positive patterns of interaction, such as Meeting 50 (Figures 0-6[A, B, and C]) compared to Meetings 80 (Figures 0-7[A, B, and C]) and 90 (Figures 0-9[A, B, and C]).

Balance "communication", "reaction", and "action" with media use.

Teams that balance the process of communication, reaction, and action achieve synergy. Teams that focus solely on "describing" and "explaining", such as Meeting 1, maintain the status quo [Figure 6-7]. No meetings exhibited examples of teams focusing solely on "action" or "reaction". This suggests that "action" is dependent on "communication". In all meetings "reaction" plays a smaller role as a percentage of time, but in the analysis of the moment-to-moment interaction, some teams, Meetings 50 and 60 and to some extent Meeting 1, balanced the three processes of "communication", "reaction", and "action", and these teams achieved synergy. Although, reaction accounts for only 2% of time, the teams that intermittently spend a few moments joking, laughing, or socializing, achieved more synergy (Meetings 50 and 60) and balanced rich media use with low media use. This suggests that teams naturally balance the processes of media use with team interaction.

Balance "project", "process", and "interpersonal" needs with media use.

Teams that balance the needs of the project, the meeting process, and the interpersonal interactions also achieved synergy. Teams that integrated media use into interpersonal relations, meeting process ("coordinating" and "structuring"), and project-level interactions ("producing" and "acting") achieved synergy. Teams that limited their use of media to one level of interaction, primarily project level use, were less synergistic (Meetings 1 and 80). For example, the team in Meeting 80 did not maintain the flow of the meeting, or attend to needs between meeting participants, such as information exchange needs, or simply did not respond to requests by participants. In Meeting 70, the team also did not maintain the flow of the meeting, participants left and re-joined the meeting, to attend to other issues or find information to answer questions They did not balance the needs of the process and the interpersonal interactions and this led to partial breakdowns. In Meeting 1, the team focused on project and meeting-level goals, but did not balance that with interpersonal interactions or communication between the meeting participants.

6.6.2 Media Designers and Researchers

Media designers, particularly those designing meeting environments face considerable challenges (see Chapter 1) with respect to identifying the typical user, typical tasks, and criteria to assess the media. The results from MIA show a range of how teams used a variety of media environments, from informal, paper-based, to well-designed, digital media environments. The focus here was not on specific features of media that most media designers spend time designing, implementing, and testing. Instead, the focus was on how teams enacted media in the context of meeting activity. Features of the media, though, do play a role in the process and affect to what extent teams use, interact, and engage with the media. For the most part, though, media features were not the root cause or limiting factor in how teams used the media.

Thus, the primary recommendation for media designers is to examine the recommendations for practitioners and consider how features of the media could support those recommendations. Here I draw upon those recommendations and findings from applying MIA to suggest aspects of media environments that media designers should consider and suggestions for future research related to media design:

Design for transitions.

Transitions between media and between media of different accessibility impede the flow of the meeting and are often associated with less rich interaction (Case Example C). Teams also avoid transitions, such as noted in Example 10, when teams do not want to spend time to find information or move from one location of media to another. Given the wide variety of project information and ad-hoc task environment, it is doubtful that a single medium can support all meeting tasks. None of the media used by the teams had any specific features for managing transitions. Instead, the teams must manage the process of transitioning. Media designs must consider how features can support transitions between media.

Design for mixing media.

One of the challenges with the AEC meeting context for media designers is the use of paper and digital media. For media designers, the goal is typically to digitize all forms of media and to create a paperless media environment. The two meeting media environments associated with synergy were not mixed media environments. This suggests that media designers and researchers need to investigate what aspects of mixed media environments, accessibility, type of media, etc., are associated with more synergistic team interaction.

Design for multiple displays.

Three of the meetings analyzed included multi-display media environments. These multi-display environments varied in two key aspects: 1) the function of the display and 2) management of the display. In Meeting 50, the team assigned a distinct function to each display. One display captured project issues and acted as a coordination device. The other display acted as a communicative and workspace device. Transitions between the media related to differences in media purpose and team interaction. The pattern of mediated interaction is synergy/rich media use. In Meeting 80, both displays acted as communicative devices. The transitions between the displays were associated with less rich interaction. In Meeting 30, the

displays had no specific purpose, since the teams were exploring their use and transitions between the two resulted in no change in team interaction but also did not lead to richer team interaction. These patterns of mediated interaction are in the status quo/breakdown and medium/low media use zones. This suggests that media designers should assign specific functions to a display and provide guidance to users to identify the purpose of each display.

Assess media.

Teams and media designers rarely assess the benefits of a medium in the meeting context. As noted in Chapter 1, it is difficult to assess the benefits of a single medium in a multiple media environment. MIA offers an approach to examine the use of a single medium in relation to all media in the meeting environment. It first offers a method to identify whether teams use a specific media and if so, how often, the level of interactivity with the medium, and for what purpose. MIA offers media designers with a set of constructs to examine the media use more broadly and then to examine whether specific features affect any aspect of media use and in turn affect team interaction.

6.7 Future Research and Limitations of MIA

MIA is a descriptive approach to examine the role of media use in team interaction in AEC project meetings. It examines this dynamic at the micro-level in multi-disciplinary, multiple media, face-to-face meeting contexts. MIA is a first step towards a normative model of team interaction and media use—a science of team interaction and media use. MIA describes, but does not yet explain, the differences in team interaction and media use.

MIA does not examine specific features of media or the use of online media for project meetings. The construct to compare media use includes examination of the physical interaction with media and may not be suitable to study online media use. Future research may broaden the definition of the Richness of Media Use and its concepts to allow for comparison of media use in online contexts.

Another aspect of use that this study did not investigate is the ‘fit’ between the meeting tasks (or goals) and the features of the media environment. The teams in Meetings 50 and 80, for example, achieved synergy using media that supported the communication of complex project information. Could these teams achieve the same level of synergy with other media? The team in Meeting 60 used paper media that supported the conceptual design. Could they achieve the same level of synergy with digital media? The rich use of media during periods of synergy in these meetings suggest a “fit” between the task, the medium, and how the team uses the media (see Chapter 2). Future researchers can use MIA to compare the patterns of mediated interaction for different media environments (and different features) in similar meetings types.

A key assumption in MIA is that all meetings are assessable relative to some standard of performance regardless of the meeting tasks. That is, regardless of whether the meeting is to provide information, brainstorm solutions, review project designs, or address a specific issue, all teams should achieve some level of synergy and balance communication, reaction, and action. However, some meetings may never be as synergistic as other meetings due to the tasks or goal for the meeting. For example, Meeting 1 was a

schedule review meeting and the primary goal was to communicate the proposed schedule. By all accounts, it was a "good" schedule review meeting. The team spent 74% of the time in the status quo zone, 15% in the synergy zone, and 11% in the breakdown zone. On the other hand, Meetings 50 and 60 that involved "action" tasks—coordination and conceptual design—were more synergistic. Is it possible for certain types of meetings, such as "informational" meetings, to be synergistic based on the operational definition of synergy defined in this dissertation? Or is some aspect of the team interaction not yet captured in the operational definition for synergy or Richness of Interaction? Or, is avoiding breakdowns a better indicator of the meeting performance for some meetings?

Another limitation of MIA is methodological and may limit its use by practitioners, media designers, or researchers. The approach is labor intensive and time consuming. I discovered key aspects of the relationship between team interaction and media use by performing the detailed micro-level analysis. For broader use, though, additional simplification of the MIA analytic scheme and/or the granularity of analysis may be necessary. Are there ways to synthesize the MIA concepts or to apply the concepts without detailed coding of meeting interaction?

6.8 Discussion

The MIA approach is a novel approach to study and explore the relationship between media use and team interaction. As shown by the MIA diagrams this relationship is complex and messy. The answer to whether media use shapes team interaction or team interaction shapes media use is messy. Prior methods abstract and generalize this relationship and reduce behavior to numbers that miss the complexities of the dynamic between media use and team interaction. The MIA spectra and MIA diagrams capture differences in how teams use media and how teams interact and illustrate the relationship between these processes. I developed an approach that lets the data and visualizations speak for themselves. The MIA visualizations show the messy and ad hoc nature of meeting interaction from two distinct perspectives. However, even these diagrams require narratives for explanation, particularly to probe further and to examine the aspects of the interaction that lead to synergy or breakdowns.

What do these findings tell us about the relationship between media use and team interaction? The findings show a mutual balancing process of media use and team interaction in the groups that spent more time synergizing. That is, the teams that make media part of the team and use media to communicate, react and act, at all levels of interaction are more synergistic. It suggests that as teams integrate media into key aspects of meeting interaction, the teams move towards synergy. The teams that view media as a sideline player or relegate its role as a supporter experience more breakdowns and generally do not move beyond the status quo. The findings are inconclusive with respect to what the ideal pattern of mediated interaction is or what constitutes ideal team interaction or ideal media use.

The findings do suggest that maintaining synergy for extended periods of time or rich media use may not be optimal. No team was synergistic for more than a few interactions and no team used media richly for more than several minutes. Rather, achieving synergy is the result of cycles of team interaction that balance communication, reaction, and action. Synergy is the culmination of these processes unfolding at the

interpersonal interaction level, meeting process, and then at the project level. That is, the successful resolution of project issues and generation of ideas requires balancing the needs of the participants including their interpersonal relations, the need to maintain the meeting process, and to address project issues. Thus, assuming that teams should be 100% synergistic or "on" at all times is unrealistic.

Similarly, assuming that teams should use media at all times and for all meeting tasks is also not ideal. The patterns of mediated interaction show that even the teams that integrate media use into key aspects of team interaction at various periods throughout the meeting balance that with periods of no use. The meetings with the most synergy balanced these processes and had lines of mediated interaction balance that extended from one corner of the MIA diagram to the upper right corner of the MIA diagram, i.e., synergy with rich media use.

In summary, the MIA approach includes a model, analytic scheme, Richness spectra, and MIA diagrams that may be used in combination or independently to explore the relationship between media use and team interaction. The model of mediated interaction builds on prior models and is suited to study natural interaction and use of multiple media. The analytic scheme captures the concepts of MIM and provides a basis to analyze and study interaction from multiple perspectives. The Richness spectra offer two multi-categorical constructs to describe and compare meeting interaction relative to typical interaction and use of mixed media. Finally, the MIA diagrams use the data captured and the constructs to explore the moment-to-moment changes in mediated interaction and to describe large and small patterns of mediated interactions and their relation to one another. These patterns are potential resources for practitioners and media designers to improve meeting practice and media design.