Study of Productivity Rates for

Geographically Distributed Agile Teams

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Productivity Study of Distributed Agile Teams

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Abstract

A reality for many information technology (IT) organizations is the need to hire IT talent from other cities or countries to supplement their employee staff. As organizations extend their software development work to remote locations, however, a distinct productivity gap can emerge between co-located and distributed teams. The problem this study addresses is the reduced productivity levels for teams practicing the Agile methodology when team members are distributed by location or time zone. Specifically, it was unknown if there are organizational factors which can improve the productivity of these distributed development teams. The purpose of this study was to determine whether any amount of separation of team members impacts productivity, or if various degrees of time zone overlap allows for sufficient synchronous communication to overcome the communication lag inherit with having distributed teams. Productivity was measured by the number of story points per cycle day completed by the team. Two additional variables were collected to study the impact of sourcing and task complexity on distributed team productivity. A quantitative data analysis was conducted on a large, globally distributed technology organization practicing the Agile methodology across the Americas, Europe, Africa, Asia, and Australia. Teams were classified in the study based on the amount of time zone overlap of the team members. The results of the study found that teams which were co-located or had any amount of time zone overlap performed at similar levels of productivity, while teams with no overlapping business day experienced significantly lower levels of productivity ($p < .05$). Conversely, sourcing of the resources either as contractors or employees did not demonstrate a significant difference in team productivity. The data analysis on task complexity showed mixed results; there was a different level of productivity when some teams were working tasks of different complexity, but the data was further nuanced by team member location. This study indicates the importance of resource location as a key factor in team productivity. Further study on organizational design could be beneficial to better understand how organizations should select locations to optimize productivity.

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Chapter 1: Introduction

According to the Bureau of Labor Statistics (2015), the software engineering field is expected to grow by 22% from 2012 to 2022. Conversely, a study conducted by Headlight, LLC (Supply and Demand Gap of Software Developers in the United States, 2015) concluded that less than half of the needed software engineering talent will be graduating from universities in the United States. A similar outlook is reported by the Institute of Electrical and Electronics Engineers (IEEE) for the engineering talent needed across Europe (Schneiderman, 2015). Resources with information technology (IT) skills are used in a wide range of functions for many organizations, supporting everything from administrative functions, such as accounting and payroll operations, to business functions, such as marketing and sales. Since many companies now rely heavily on IT functions, the looming shortage of IT graduates may cause the demand for software engineers to outpace the supply in many countries (Olson, 2015).

To solve for this expected domestic shortage of IT workers, companies have started to fill that void with software engineering talent from other locations to supplement or replace their own domestic staff (Dobbs, Manyika, & Woetzel, 2015). Companies have added distributed team members from other offices, cites, or countries to augment their existing workforce. As companies leverage a globally distributed workforce, though, a distinct productivity gap has emerged between co-located and distributed teams, with co-located teams consistently delivering more productive results than their distributed counterparts (Cataldo & Herbsleb, 2008; Sidhu & Volberda, 2011). The most common reason cited for this productivity delta has been attributed to ineffective communication practices among distributed teams, which leads to inefficient coordination of tasks.

Software development is an engineering practice, which requires extensive knowledge sharing and coordination (Razzak & Ahmed, 2014). While it is often assumed that software development is a solitary function, it is in fact a highly integrated and cooperative practice which requires a great deal of communication between team members to be effective (Herbsleb & Mockus, 2003); therefore, productivity can be impeded when project team members are working together but in separate locations. This productivity level is further impacted, depending on the frequency of communication required by the software development methodology selected by the organization.

Software development teams globally are increasingly selecting the practices of the Agile methodology over more traditional software development lifecycle methodologies. Traditional methodologies include the Waterfall Development methodology formalized in the 1980s, the Rapid Application Development methodology introduced in the 1990s, or the Extreme Programming methodology introduced in 1999 (Rigby, Sutherland, & Takeuchi, 2016). The rationale used by organizations to adopt Agile development methods is largely due to the perceived benefits, including faster delivery of software artifacts, better engagement of stakeholders, and a higher quality final deliverable (Kautz, Johansen, & Uldahl, 2014).

Agile as a methodology was first introduced in 2001, but was enhanced into a framework that could be used by an entire enterprise in 2010 with the introduction of the Scaled Agile Framework, or SAFe® ("SAFe 4.0 for Lean Software and Systems Engineering," n.d.). The key to running a successful Agile project is to follow as closely as possible to the twelve principles outlined in the Agile Manifesto (Batra, 2009), which are listed in Appendix A. Organizations practicing the Agile methodology attempt to practice all twelve principles of the manifesto.

The foundation of the Agile methodology is frequent and effective communication across a software development team. The communication challenge for organizations with globally distributed software development teams, then, is in complying with the sixth Agile principal, which indicates that the most effective communication method for Agile teams is to deliver information face to face (Binder, Aillaud, & Schilli, 2014). When companies are practicing Agile using a globally distributed workforce, they are challenged with establishing an environment which enables effective and timely communication and collaboration (Herbsleb & Mockus, 2003).

There are multiple examples of theories and related research around the linkage between communication practices and globally distributed Agile software development teams. Communication has long been identified as a key component of successful software development projects even before the adoption of the Agile methodology (Wagner & Ruhe, 2008), and communication practices are a core component of the Agile methodology for developing software (Serrador & Pinto, 2015). The Behavioral Complexity theory and the Leader-Member Exchange theory (Jawadi, Daassi, Favier, & Kalika, 2013) are two theories which focus on the importance of leaders in facilitating a high quality exchange of information between distributed team members. Another related theory, Hall’s Cross-Cultural Theory (Zakaria, 2016), has been used to explain the communication styles exhibited during decision making activities on globally distributed teams.

There are three theories in particular, though, which focus on the communication behavior for coordination of specific work tasks of software development teams. The Coordination Theory (Cummings, Espinosa, & Pickering, 2009) and the Media Synchronicity Theory (Espinosa, Nan, & Carmel, 2015) address the coordination of tasks and information sharing to complete those tasks. Conway's Law additionally addresses organizational communication practices and their impact on the software architecture designed by the organization (Bano, Zowghi, & Sarkissian, 2016). One application of these theories has been that organizations which do not provide a framework for frequent and synchronous communication for distributed members of a team will observe productivity leakage with the output of the software products delivered (Sidhu & Volberda, 2011).

This productivity loss for geographically distributed Agile teams is not generally disputed (Sidhu & Volberda, 2011), but the ability to make accommodations in communication practices to offset the productivity loss has not been well documented (Kahn & Kahn, 2014). A key challenge to conducting research on the topic has been having an effective way to evaluate productivity. Prior studies on the topic of distributed Agile team productivity have relied upon the opinion of the executive management team or project managers to gauge whether their team practices were productive (Saafein & Shaykhian, 2014; Sarker & Sarker, 2009). This approach leads to instrumentation differences, which challenge the validity of the findings, since each respondent would have their own standard for success or productivity.

While significant research supports the opinion that distributed development teams practicing the Agile methodology are less productive than their co-located counterparts, there has not yet been sufficient research to confirm if these productivity difference are due to lack of face-to-face communication, due to lack of synchronous communication alone, or due to some other factor. Further research was also needed to explore the role of distributed synchronous communication and whether it could deliver the same benefits as face-to-face communication, thereby facilitating the effective communication and collaboration essential for team productivity.

A recent laboratory study (Espinosa, et. al., 2015) explored the value of synchronous communication by testing what occurs when a team's temporal pattern of communication is altered. This research was conducted in a controlled experiment, using university student participants; while it simulated team members who were distributed by various degrees of temporal pattern separation, the results cannot necessarily be applied to a business setting without further research. The study was not attempting to build actual software; instead, students were given discrete tasks similar to software development tasks to coordinate with team members in different simulated time zones. The study's results indicated that the frequency of synchronous communication had the most impact on productivity as opposed to the impact of team member location alone.

In the study, team members with overlapping work hours had the ability to interact in real-time. Team members with more simulated overlapping work hours were able to complete more of their tasks quickly and accurately. Further study was needed, though, to determine if the same results would hold true when teams are physically separated in an actual business setting and attempting to complete more complicated tasks, such as software development tasks.

Statement of the Problem

The problem this study addressed was the documented levels of reduced productivity (Cataldo & Herbsleb, 2008; Sidhu & Volberda, 2011) experienced by distributed software development teams attempting to practice the Agile methodology. It was unknown whether there are specific team design attributes organizations can implement which would increase productivity for distributed teams practicing the Agile methodology. Several recent studies of globally distributed software development teams indicated they indeed appear to have a distinct disadvantage when attempting to practice the Agile methodology (Alzoubi, Gill, & Al-Ani, 2016; Cummings, et. al., 2009).

Several of these prior studies concluded that delayed communication was the cause of the productivity loss, since face-to-face communication for distributed teams was not possible (Wagstrom, Herbsleb, & Carley, 2010; Yagüe, Garbajosa, Díaz, & González, 2016). The assumption by most researchers of Agile project productivity, though, has been that synchronous communication can only be effectively conducted in person. These studies were largely conducted prior to synchronous technology tools being widely available within organizations and societal acceptance of this technology. Further study was needed to determine if the benefits of face-to-face communication could be simulated with communication alignment, by adjusting the time of day teams communicated, or with the help of communication technology, such as instant messaging, video and audio conferencing, and online collaboration tools.

The closest quantitative simulation of different temporal patterns of communication was conducted in a laboratory setting and not specifically practicing the Agile methodology (Espinosa, et. al., 2015). A quantitative study of the productivity of teams practicing Agile in an organizational setting, based on a uniform measurement standard across the various teams studied, had yet to be contributed to the body of knowledge around team productivity and the impact of communication alignment.

Purpose of the Study

The purpose of this quantitative research study was to determine which team variables had the most impact on productivity for co-located and distributed teams. Productivity of software development teams for this research was defined by their ability to deliver software on schedule, on budget, and with high quality/low defects. The usage of an enterprise Agile methodology provided a standard unit of measurement, since tasks were consistently estimated in size based on story points, with a common definition of approximate time each story point represented. Unlike normal Scrum, where each team's story point estimates are relative only to that team, practicing scaled agile requires a normalized estimating practice, so that work which must span multiple groups uses a common definition of the effort required. In this study, the product owner or scrum master decided if each work package met their definition of quality by marking the work package as accepted. Communication within the team and communication with the product owner are key elements in an Agile project to meeting this measurement standard (Bass, 2015).

As noted earlier, many of the studies on agile team productivity have explored the impact of communication on team productivity, but researchers had not fully explored if the timing of communication was the key factor to making software teams successful, or if other factors have an impact on communication effectiveness. Additional research had proposed that other factors beyond communication, such as the complexity of the work assignment (Zhan, Zhou, & Zhao, 2012) or the resource sourcing arrangement on the team (Bidwell, 2009) may actually have more impact on productivity than spatial or temporal distances.

The intent of this study was to observe global software development teams with varying degrees of synchronous and asynchronous information sharing. Using quantitative data captured from an enterprise software life-cycle management tool across a twelve-week period, this study measured task velocity for teams with members spread across different geographies completing similarly high and low complexity tasks while practicing the Agile methodology. Team member work locations were captured to compare team output across teams with different degrees of business day overlap. Team member sourcing was captured to determine if employee based teams performed with higher levels of productivity than their contingent resource counterparts. The purpose of collecting these variables was to determine the most impactful team attributes in which companies could invest to sustain productive distributed teams.

Theoretical/Conceptual Framework

Theories related to task coordination and knowledge sharing provided the theoretical framework for this research proposal. Three theories in particular are highlighted below regarding the need for coordination of tasks and the knowledge sharing needed to accurately conduct this coordination. The Coordination Theory, the Media Synchronicity Theory, and Conway's Law provided the theoretical basis for this research, because all three theories focus on the task and communication needs of teams. To evaluate the problem of restricted communication patterns for globally distributed software development teams, particularly teams attempting to practice the Agile methodology, a data analysis of software development productivity rates was proposed. Table 1 outlines the theories of most relevance to this research:

Table 1

Productivity Theories

Productivity Observation	**Related Theory**
Software development work must be decomposed into different tasks, and the completion of those tasks must be highly coordinated by the team; dividing tasks across virtual teams can be more challenging due to coordination delay.	The Coordination Theory
Team members must converge their thinking on these tasks by sharing their understanding, asking for clarification, and agreeing upon a design approach. This convergence is challenged or delayed due to separation of temporal patterns.	The Media Synchronicity Theory
When knowledge sharing is ineffective and teams are not able to effectively converge their thinking, the software systems constructed by these teams are often fragmented and require significant rework to achieve the intended result. This rework impedes productivity for the team.	Conway's Law

These three theories were of significance to Agile development, because the Agile methodology focuses on the decomposition of tasks and the team's understanding for how to best deliver the task.

As noted in the introduction, there are multiple theories which enhance the understanding about the productivity challenges of globally distributed teams. The three observations and theories in the prior table help explain the productivity challenges specific to attempting software development with distributed team members. Each of these observations contributes to an understanding about the reduced level of productivity for global virtual teams, and each of the symptoms described can be tied to the related research. The corresponding research has documented the impact of these theories through scientific study.

The Coordination Theory. Teams building software must effectively coordinate their activities. The Coordination Theory (Cummings, et. al. 2009) explains why team members need to decompose work into smaller work units, and the team must agree on how the work will be divided up. With distributed teams, the ability to effectively divide work is impeded by the distance of team members. The purpose of a 2009 study was to test seven hypotheses about coordination delay, but the most relevant to this research tested crossing spatial boundaries with different degrees of overlapping work hours; this distance would be associated with an increase of coordination delay. The study design used interviews and surveys to collect data from over 675 projects. They measured individual team member information, such as the person's role on the project, time spent on the project, location and time zone, and communication methods used.

The research found that having even a small amount of overlap in work hours encouraged team members to leverage communication tools, but it also revealed that having the tools available was not sufficient to avoid the coordination delay. The research found that workers also need to pay attention to the soft factors, such as team building, for the tools to be effective in coordination. While the research was relevant, the data was anecdotal and did not attempt to quantify if the work completed was accurate and highly productive. It did, however, establish sufficient evidence to do further research, which could collect more quantitative data about quality, speed, and team distance.

The Media Synchronicity Theory. The Media Synchronicity Theory proposes that teams must agree upon or converge on a set of ideas through activities such as immediate feedback; this feedback is accomplished by a frequent exchange of information across team members (Espinosa, et. al., 2015). The challenge for virtual teams is that this convergence is impeded if the exchange of information is not bi-directional. In a 2015 research study by Espinosa, Nan and Carmel, they attempted to explore different degrees of temporal pattern separation to determine if time zone separation, more than geographic separation, plays a bigger role in the richness of communication exchanged between distributed team members.

Using a quantitative lab experiment, the study simulated short imaginary workdays in which small distributed teams were assigned a digital task to complete. The tasks required a high degree of coordination to be successful. The research team collected a number of variables, such as speed, accuracy, and time zone overlap of the team members. The study confirmed that although spatial distance may matter, time zone distance is actually the more important variable. Prior research by members of this team (Espinosa, Slaughter, Kraut, & Herbsleb, 2007) demonstrated that information and communication technologies can help bridge the spatial gap; however, these technologies alone did little to bridge the temporal pattern gap. The study found that behaviors which encourage interactive communication and turn-taking had the most impact on quality as well as speed. The study was well designed and introduced different simulations of spatial or time zone separation. The findings presented a new area of research to pursue outside of a laboratory setting, to determine if the findings could be extrapolated to actual distributed software development teams.

Conway's Law. A third theory which deals with both communication patterns and the organizational structure of a team was described by Melvin Conway in 1968. He observed that the way organizations are structured and communicate influences how systems created by those organizations are ultimately designed as well (Blatter, Gledhill, Krein, & Knutson, 2013). A recent experimental study was conducted to determine if Conway's Law still holds true in a controlled setting (Blatter, et. al., 2013).

The experiment required enforcing specific communication patterns on the subjects. Participants were all seniors studying computer science at Brigham Young University. The variables in the study were the communication treatment and the organizational structure. The study found that Conway's law was nuanced, in that smaller organizations did create systems which mirrored the organization's communication structure, but participants also found ways to compensate for various communication barriers. The study was important for this research, as it demonstrated that Conway's Law was still relevant and accurate, showing that productivity was indeed reduced unless teams made special accommodations to counter the effect of separation. The study also found that the theory was nuanced, because when developers made accommodations, they could overcome organizational barriers to productivity.

A limitation of the Brigham Young experiment, however, was that participants were enticed to participate in the study, either through a financial incentive or extra credit in the course, and may have been differently motivated to successfully share knowledge than employees within an organization would be. Additionally, the experiment did not attempt to control if participants knew each other prior to the study, which also would impact the level of team trust. The study itself did not substantially change the support for Conway's Law, but it demonstrated the need for further study in light of the availability of more recent communication tools and the ability for distributed workers to find different collaboration strategies.

While hundreds of studies have been conducted to demonstrate Conway's law (Bailey, Godbole, Knutson, & Krein, 2013), when applied to distributed software development teams, there have been insufficient studies to determine if team design can be altered to give Agile teams the same synchronous communication structure as co-located teams. Instead, most applications of the theory focused on separating the work tasks so that distributed team members can work asynchronously. While this can be a simple solution to distributing work to a global team, it also leads to other problems of isolation and silos of knowledge when the software these teams build must integrate with the rest of the organization (Fowler, 2016).

Need for more research. Most studies concur that when distributed teams are attempting to follow the Agile methodology, they have difficulty complying with the methodology's sixth principle, which is a requirement that communication is best when delivered face to face (Batra, 2009). Even when agile teams are co-located, productivity can suffer if the team personality and design are not considered when assembling the team (de O. Melo, Cruzes, Kon, & Conradi, 2013). These factors are exacerbated when team members are distributed and separated by different time zones as well as geographic distances. There was a need for additional research leveraging the Coordination Theory, the Media Synchronicity Theory, and Conway's Law, to explore whether advances in recent information technology tools would enable sufficient synchronous communication to yield the same benefits as face-to-face, co-located communication for distributed teams.

Nature of the Study

A quantitative data analysis was conducted, extracting data from a software development lifecycle (SDLC) tool to measure the velocity of multiple Agile software development teams. The study documented different temporal patterns of communication for the teams in the study to determine if the temporal pattern had an effect on team velocity. While many different productivity instruments have been developed, none have been successful in measuring productivity across different technologies, industries, or teams. This study's measurement of productivity was based on velocity for each team, measuring the number of story points completed during the work days available per story.

Comparing teams to each other can be problematic, as teams have different skill levels, and work on software with different levels of complexity, and where the complexity standard may be different from group to group. This study focused only on Scrum Teams practicing the SAFe® methodology and using a normalized story pointing system. The Fibonacci Sequence is used by most Agile teams to determine task complexity. When Agile is practiced at an enterprise level, teams are encouraged to use the same range of story points to estimate low, medium, and high complexity tasks across each team, and to normalize the definition of the meaning of story points. The study collected data from Agile teams, measuring a span of twelve weeks of work, to avoid significant attrition of team members which could impact the team's productivity.

Teams were selected from a large, multi-national organization with development teams across the globe. Participants were from software development teams distributed across locations in different cities in North and South America, Europe, Africa, and Asia Pacific countries. Teams studied were comprised of members who were completely co-located, members in the same temporal pattern, members who had less than four hours of temporal pattern overlap, and members who have no temporal pattern overlap. The organization studied offered an array of collaboration tools, including video and audio conferencing, instant messaging, email, knowledge repositories, chat rooms, mobile channels, desktop sharing, and document sharing. Each of these collaborations options were equally available to all teams selected for inclusion in the study.

Research Questions

The design of this research was to study teams which have the ability to communicate both synchronously and asynchronously. The primary research question was whether the availability of any amount of synchronous communication time contributed to a team's output productivity. While communication is often noted as a key element of productivity, this research additionally studied if task complexity or team staffing composition played a more important role in team productivity when teams were distributed across different time zones.

Building on the research conducted by Espinosa, Nan, and Carmel (2015), this study further explored the following primary research question:

> **Q1** Amongst Agile software development teams using information communication technology tools, to what extent, if any, does the ability for various periods of synchronous communication during the work day impact team productivity?

Communication factors which have been identified through previous studies as having an impact on Agile team productivity involve communication timeliness and communication effectiveness (Alzoubi, et. al., 2016). The expectation for this study was that as the amount of synchronous communication time possible for a team increased, their task completion velocity would also increase.

Additionally, while it is understood that more complex tasks take longer to complete than less complex tasks, the impact of synchronous communication and task complexity had not been well documented. Expanding on the first research question, this research also studied:

Q2. How does the level of task complexity impact the productivity of teams practicing distributed Agile with various degrees of geographic separation?

Task complexity has been documented as a factor impacting team productivity, with more complex tasks being more difficult to communicate across a distributed team (Zhan, et. al., 2012). For Agile projects, the velocity of more complex tasks was not expected to be different than in less complex tasks, though, since team members should have factored in task difficulty when estimating their work. This research analyzed if a task's complexity had any velocity impact regardless of location, or if the impact was nuanced based on team member location.

A third research question documented by this study was whether the team affinity, based on sourcing of the resources, had any impact on productivity. Sourcing was defined as whether team members were employees of the firm or outsourced through contingent agencies. This study additionally questioned whether a team member's sourcing had a stronger impact when teams were separated by spatial or time zone differences. As a result, this research further studied:

Q3. To what extent, if any, does the sourcing of an Agile team impact the productivity of teams with various degrees of geographic separation?

While the impact of sourcing on productivity is not a well-accepted causal relationship (Fariñas, López, & Martín-Marcos, 2016), there are still IT organizations holding the view that non employees are less invested in a company's success and are thus less productive (Broschak, Davis-Blake, & Block, 2008). This research was intended to also determine if co-located or distributed contingent teams were equally as productive as teams comprised of all employees or a mix of employee/contingent resources.

A final consideration when evaluating communication effectiveness and comparing teams across different geographies was to consider their ability to communicate linguistically. To rule out language barriers as a contributing factor in productivity, only distributed teams which had been identified by the organization's management team as having a proficiency level with the English language were candidates for the study. Since the majority of employees in the study organization primarily communicated through English, teams where the majority of team members did not have a basic level of competency in English were eliminated from the study.

Hypotheses

$H1_0$: There is no significant difference in task velocity rates for distributed and co-located teams.

$H1_a$: There is a significant difference in task velocity rates between teams which are co-located, distributed with similar temporal patterns, and distributed with mixed temporal patterns.

$H2_0$: There is no significant difference in task velocity rates for tasks of different complexity for teams, regardless of team member location.

$H2_a$: There is a significant difference in task velocity rates, based on task complexity, between teams which are co-located, distributed with similar temporal patterns, and distributed with mixed temporal patterns.

$H3_0$: There is no significant difference in task velocity rates for teams comprised of different sourcing strategies, regardless of team member location.

$H3_a$: There is a significant difference in task velocity rates, based on team sourcing strategies, between teams which are co-located, distributed with similar temporal patterns, and distributed with mixed temporal patterns.

Significance of the Study

This research provided some insight into factors which improve or inhibit collaboration in distributed teams. A reality for many large IT organizations is that they will need to leverage a distributed workforce, either domestically or globally (Olson, 2015). Any company with a distributed work force attempting to practice the Agile methodology is similarly impacted by the productivity loss from coordination delays of distributed teams (Dereli, 2015). This study attempted to identify resource distribution practices or hiring strategies companies can implement to achieve the highest productivity from their workforce.

The topic is of interest to software development managers who must assign work to global teams. A 2015 report by McKinsey and Company concluded that a labor gap is on the horizon globally by the year 2020, resulting in a shortage of over 40 million highly-skilled workers, particularly in the technology and health care sectors (Olson, 2015). To solve for this gap in supply and demand, the McKinsey report suggested that companies will have to consider leveraging talent from across the globe to supplement their own staff or to completely fulfill their IT requirements.

Studying productivity across different software development teams has also been difficult for other studies, since each team is made up of different skills, experience, or complexity of work. The opportunity to study an organization practicing the scaled Agile methodology provided a uniform method for estimating team work and measuring the resultant velocity of software development teams. Velocity and the rate of delivery of software were key measures of productivity used in this study. By selecting the SAFe® methodology, it was feasible to compare software development teams regardless of skill or experience of the workers.

Finally, the outcome of the study was timely, since as noted in the introduction, there is a looming shortage of skilled software engineering talent to meet the global demand for this resource skill. Companies of medium or large size will likely need to adopt some form of a globally distributed workforce in order to source the software engineering talent they need in the very near future. When organizations require teams to collaborate across multiple locations, they often experience productivity loss but are unable to find acceptable strategies to minimize or manage the loss. The intended usage of this study's findings is to identify strategies which minimize or eliminate the loss of team productivity.

Definition of Key Terms

For the purpose of this study, a few key terms are defined in this section. Many of these terms relate to the Agile methodology, but the terminology can be different depending on which version of Agile is being practiced at an organization. The terms in this document will be defined by the following:

Agile and Waterfall methodologies. When referenced in this study, if capitalized, Agile refers to a specific software development methodology, typically time-boxed, based on small, iterative development cycles of build, measure, learn (Scrum Glossary, n.d.). When not capitalized it refers to teams attempting to move quickly and easily. The Waterfall software development methodology is a sequential process, which typically flows downward similar to a waterfall, though various project phases which include project conception, initiation, planning, execution, monitoring, and closure performance (*A guide to the project management body of knowledge: PMBOK guide*, 2013).

Asynchronous communication. For the purposes of this study, asynchronous communication occurs between two or more individuals where the message is sent at one time and received at a later time, and where the receiver is offline and unable to respond with acknowledgement. An example would be where the message sender makes a statement through a one-way communication channel such as email, and the receiver responds several hours later with clarifying questions or comments about the message, also via a one-way communication channel back to the sender (Estler, Nordio, Furia, Meyer, & Schneider, 2014).

Cycle time and velocity. The cycle time for this study will be the time, measured in work days, which it takes for a team to deliver software from inception to a completed state (Jahr, 2014). An Agile software development team's velocity in this study will be defined by the amount of successfully delivered software, accepted by the product owner as passing all acceptance criteria, and measured by story points and cycle time to deliver. The velocity ratio collected will be story points per cycle day.

Fibonacci Sequence. The Fibonacci Sequence is a series of numbers, (0, 1, 2, 3, 5, 8, 13) with each subsequent number adding the prior two numbers together to come up with the third (Edwards, 2016). Agile teams use the Fibonacci Sequence as one way to assign relative size to the work efforts, with very small tasks rated a 1 and very large rated 13 in this example.

Productivity. Productivity for software development teams in this research is defined by their ability to deliver software on schedule, on budget, and with high quality (Wagner & Ruhe, 2008). Delivering on schedule means meeting the schedule commitments made by the development team to the project sponsor. Similarly, on budget refers to meeting the cost estimates made to the project sponsor at the start of the project. High quality means delivering working software, as validated by the project sponsor that the software meets with his or her expectations.

Scrum roles. A scrum team is a self-organizing team consisting of a product owner, business analyst, software and quality engineers, and Scrum Master (Scrum Glossary, n.d.). The role within a Scrum Team who is accountable for leading the team to accomplish the work assigned by the product owner is often called the Scrum Master (Scrum Glossary, n.d.). Other teams may continue to call this role the project manager.

Sprints and stories. A sprint is a time-boxed event, typically made up of two to four weeks in this study. Sprints are done consecutively, without intermediate gaps (Scrum Glossary, n.d.). Agile development teams work on multiple stories during each sprint period. A story is the smallest unit of work which can still deliver value back to the customer or end user (Scrum Glossary, n.d.). Teams working on stories will estimate their work in the form of story points (Rigby, et. al., 2016), which are a relative estimate of the effort required to complete an individual story. While story points do not directly equate to hours, teams will use their prior history to predict their own velocity, meaning how fast they think they can complete a task, and assign a relative number of story points to identify the relative size of the work.

Synchronous communication. For the purposes of this study, synchronous communication occurs between two or more individuals where the message is sent and received at the same time, with the opportunity for turn taking and response from the receiver. An example would be where the message sender makes a statement and the receiver responds immediately with clarifying questions or comments about the message (Estler, et. al., 2014).

Temporal patterns. For the purpose of this study, teams will be distributed both geographically and by time zones. When teams have members located in multiple time zones, this separation will be referred to as their temporal pattern (Swigger, Hoyt, Serçe, Lopez, & Alpaslan, 2012). Teams may also be distributed in the same time zone but different locations; in this case such teams would be considered to have the same temporal pattern.

Summary

Managing successful software development projects can be complex due to size of the project and the distribution and sourcing of the team. Research by Ihme, Pikkarainen, Kaariainen and Biot (2014) found that as complexity of the software development project increases, adding a distributed team to the equation means communication is an even more important element of which to be mindful. Distributed teams by their very nature will not have the same seamless communication benefits that onsite, co-located teams experience.

This study recognized these communication differences and used geographic factors to determine possible benefits to structuring teams geographically or by team work shifts. Such staffing changes can facilitate synchronous communication and be an important way managers could mitigate the communication delay inherent to distributed teams. The research further probed if the sourcing composition of the team or the complexity of work could be other factors impacting team productivity.

By varying the location, task complexity, and sourcing of the project teams, and only comparing teams working in the Scaled Agile software development methodology, this study contributed new insight into the impact of communication practices on software development team productivity. The next chapter will describe prior research on the topic of productivity factors for distributed teams and the impact which location, sourcing, and complexity might play. This chapter will also describe the theoretical framework for choosing to study the impact of team location on task productivity, and why the location of team members is important to task output.

Chapter 2: Literature Review

This literature review provides relevant background for the factors impacting global team productivity, and specifically factors impacting Agile development team productivity. As described in Chapter 1, productivity for software development teams is essential to successful project outcomes. Multiple studies predict a pending shortage of software engineering resources, which will require companies to attract and retain software development team members across diverse global locations (Iammartino, Bischoff, Willy, & Shapiro, 2016). In reviewing relevant literature on the topic of global software development team productivity, project success has most often been described as software which has been delivered on schedule, within allocated budget, and with high quality and low defects.

The desire to study the influencing factors of software engineering productivity has been pursued for decades. A seminal work initially delivered in 1980 by Wagner and Ruhe (2008) on productivity factors was updated in 2008 to review the relevance of the article the pair prepared almost forty years ago on this same topic. Their work defining the main factors influencing software developer productivity is still relevant, including a list of technical and soft factors important to productivity. Much research has been based on the key observations of Wagner and Ruhe about several important soft factors in software development team productivity, including (a) team identity, (b) turnover, (c) cohesion, (d) communication, (e) clear goals and (f) support for innovation (Sudhakar, Farooq, & Patnaik, 2012). The pair observed that most studies mainly focus on technical factors such as the software size or the product complexity, yet more than a third of the time a typical software developer spends is not concerned with technical work but is instead spent in meetings and conversations.

The purpose of this quantitative study was to help identify contributing factors for why productivity when delivering software becomes degraded as project teams are distributed both geographically and by time zone. As the literature review uncovers, for Agile distributed teams any physical separation makes it more difficult to coordinate activity and collaborate on common tasks. This separation, then, offsets and negates many of the benefits of Agile development.

The problem and purpose statements described in Chapter 1 were used to develop the keyword phrases used to search electronic journal databases at the library of Northcentral University. Much of the published research was found in accepted academic databases of EBSCOhost, ProQuest, Science Direct, and Google Scholar. A combination of the following primary key words were used in the search: (a) distributed development, (b) globally distributed teams, (c) productivity of distributed teams, (d) temporal communication, (e) communication and team dynamics, (f) team trust and distributed teams, and (g) Agile distributed development. A secondary search key was additionally applied to each of these searches to include: (a) communication challenges, (b) software development, (c) productivity factors, or (d) productivity challenges. A consistent theme began to emerge which focused on communication as a key element required for any type of team delivery effectiveness.

A great deal of the research focused on communication as a necessary ingredient to build team trust. Teams which were separated had fewer opportunities for both project and non-project related communication. This focus on communication led to the research question of this study regarding synchronous communication availability among team members. The study further probed if communication was required to be in person or could be equally accomplished through other synchronous methods and still be as effective as face-to-face availability.

Theoretical/Conceptual Framework

As described in Chapter 1, theories which were related to task coordination and knowledge sharing provided the theoretical framework for this research proposal. Additional theories provide the theoretical basis for how team members relate to each other, which is important for team unity and team trust. The focus of this research relates to task productivity, which is most impacted by communication and coordination. The additional theories were important, though, to explain why the need for adequate synchronous communication is important for team dynamics as well as task productivity. The most relevant theories related to software development and team productivity are described by the following theories and observations.

The Coordination Theory. Software developers must communicate with each other in how they plan to divide the work effort. As noted in more detail in Chapter 1, the Coordination Theory (Cummings, et. al., 2009) explains why team members need to decompose work into smaller work units and agree how the work will be divided. The relevance to this research proposal is the impact of coordinating tasks across different locations, which can cause a delay in efficiently merging the work plan. Any inefficiency leads to a delay in completing the assignment in a timely manner, due to the coordination delay in defining and assigning the tasks.

The Media Synchronicity Theory. Software developers must agree upon a common understanding of the scope of their work through collaborative tasks of asking questions, documenting their understanding, and ultimately agreeing upon a design approach as a team. Also described in Chapter 1, the Media Synchronicity Theory explains how teams must agree upon a design approach through a frequent exchange of information across team members (Espinosa, et. al., 2015). The relevance for this research occurs when this type of collaboration is impacted by communication delays due to time zone separation. When team members are separated by time zone, collaboration occurs through both synchronous and asynchronous channels. The Media Synchronicity Theory explains that when communication is asynchronous, there is a delay in synchronizing the common understanding of the task.

The Media Richness Theory. Virtual teams require the same unity as co-located teams in order to effectively collaborate on tasks, but they are often not as cohesive due to their inability to interact informally. Teams which are separated geographically, then, do not have the same opportunities as co-located teams for formal and informal communication. The opportunities for interaction are further reduced when team members are separated by different time zones and can only interact asynchronously. The Media Richness Theory explains the need for both formal and informal interactions, which is a social convention necessary for building trust and understanding. While this theory is important to understand how teams build sufficient trust to share information, it does not directly apply to how teams communicate to decompose or manage tasks.

Knowledge exchange theories. Knowledge is an important asset in an organization. Software development team members must exchange knowledge in order to accomplish their work. The Knowledge Based Theory of the Firm explains how knowledge is an important resource within organizations, and even team members who are geographically separated need access to or possess knowledge which is necessary for the firm to operate. When resources are separated, though, they have more of a challenge sharing this knowledge. The Social Exchange Theory further explains that the exchange of knowledge between two individuals is a negotiated transaction, and both parties must see the exchange as beneficial.

Without a basis of trust, this exchange of knowledge will not occur, impeding knowledge sharing. When knowledge sharing does not occur, software development tasks are not completed, delayed, or not completed correctly. While both of these theories would have relevance about the accuracy of tasks, they are not directly related to task decomposition or task coordination.

Conway's Law. As described in Chapter 1, Melvin Conway first theorized in 1968 that the way organizations are structured and in turn communicate ultimately influences the design of systems created by those organizations (Blatter, et. al., 2013). Knowledge sharing is essential to designing software which considers the entire scope of the effort and not just the isolated task of a specific developer or team. This theory is relevant to this research effort because it addresses the impact of impeded knowledge sharing on the design of the software delivered. According to Conway, the ultimate software system designed may be fragmented and work only under explicit conditions. To consider the entire scope of the effort requires a broader set of communication, but teams must be organized and encouraged to share information beyond the immediate task at hand (Bano, et. al., 2016).

Team Based Theories

All of these observations from prior research described a reduced level of productivity for global virtual teams, but not all of the theories explained why distributed teams have difficulty collaborating at a task level, which is the primarily requirement of an Agile development team. As described in chapter one, three theories in particular were of the most relevance when studying the observation that synchronous communication is the most important element of task coordination, which drives effective team productivity. Those theories of key relevance were the

Coordination Theory, the Media Synchronicity Theory, and Conway's Law, because they address the role of communication in task coordination when teams are geographically separated.

There were additional theories investigated, though, which provide background into why the separation of team members impacts effective communication. These alternate theories can be grouped into theories about team unity and team trust. These alternate theories explained why communication was a necessary element for effective team interactions. While the nature of this research is not about the richness of communications between co-workers, these alternate theories still provided valuable information for the theoretical basis for this research.

Team unity. The theory that organizations also need to recognize softer skills is related to the Media Richness Theory (MRT), which has been used to describe why virtual teams lack the ability to create oneness (Stawnicza, 2014). This theory has been used to rate the richness of various communication mediums, such as phone calls, emails, and face-to-face communication. A study by Stawnicza in 2014 attempted to observe if information communication technology (ICT) tools can provide a feeling of oneness and trust for global teams. The research was conducted by a single interviewer, and individual interviews were conducted via a series of questions, which were provided to the participant in advance. Participants were asked to rate levels of communication, trust, cross-cultural issues, one-team approach, and conflicts, along with describing communication and collaboration tools used.

The dependent variables were measurements of trust, team unity, and communication. The independent variable was the ICT. A moderating variable was age of the interviewee, which may have impacted the participant's willingness to try different types of communication technology. Data categories were compared against ICT tools used by the team and concluded that frequent communication increased the level of trust in distributed project teams. The use of

ICT was also determined to strengthen shared knowledge and encourage the motivation of team members to share more frequently, due to the ease of communication.

While the MRT was a good theory to explore in determining if recent advances in ICT tools could improve team trust and unity, the findings of the ICT study did not substantially contribute to the theory, as the data collected was largely opinion based, and the population size was small, not diverse, and limited to a single geography. A more helpful additional study would include the capture of multiple distances separated by time zones to determine if the tools were equally effective across various separation variables. The study was helpful, though, in that it substantiated similar studies (Soderberg, Krishna, & Bjorn, 2013) about the importance of the role of communication in building team unity and trust.

Team trust. A fourth related set of theories are the Knowledge Based Theory of The Firm and The Social Exchange Theory, which have been used to explain the relationship between knowledge sharing, trust, and team effectiveness on virtual teams (Alsharo, Gregg, & Ramirez, 2016). The Knowledge Based Theory of the Firm proposes that knowledge is the most strategically important resource in an organization; the Social Exchange theory describes the elements of social capital, such as trust, human networks, and social norms; the theory proposes that people will exchange this capital based on their own evaluation of benefit and alternatives. A 2016 study (Alsharo, et. al., 2016) observed virtual team effectiveness in light of social capital and knowledge sharing. The data was collected via a survey with participants who were confirmed to be part of a global team.

The variables of interest in the study were knowledge sharing, trust, collaboration, and team effectiveness. The research found that knowledge sharing positively influenced trust and collaboration among virtual team members; the findings were consistent with other studies on knowledge sharing and social capital, which also found that these factors were associated with high levels of team performance (Lee, et. al., 2015). The study further found that while trust positively influences virtual team collaboration, it did not translate into a similar direct effect on team effectiveness. This second finding was surprising and may imply that too much emphasis had been placed on the need for virtual teams to establish a trust foundation. The study indicates that further research on the true impact of trust on team productivity is needed.

The Role of Communication and Coordination

While it is important to understand how teams interact, there is still some debate in the literature about the amount of trust a team needs for effective communication. There is consistent agreement in these research studies that communication is key to understanding a task and coordination of work activities. The three theories most related to communication and task completion, as described previously, appear in multiple research studies as the theoretical basis for the study. The Coordination Theory explains why virtual teams working on a software development project have a difficult time coordinating task decomposition, while the Media Synchronicity theory explains why the entire virtual team must have the same understanding of the tasks they are completing. Conway's Law goes on to describe how the design of the output of the tasks is a mirror of the communication structure put in place for the team.

All three of these theories support the conceptual framework outlined in this literature review and show how Agile teams, when separated geographically or by time zone, have a degraded ability to communicate and thus are have fewer opportunities to coordinate work effectively. While prior research documented the degraded productivity of distributed teams, there were few studies attempting to explain what caused communication to degrade when teams were working from separate locations. Many of the studies assumed that any degree of separation caused productivity leakage without further exploring if different degrees of separation had a different level of impact. The following section details the research conducted to date on the topic of globally distributed teams and factors which impact their productivity.

Globally Distributed Team Literature Review

A brief review of the current literature on the topic of globally distributed software development teams practicing the Agile methodology leveraged the theoretical framework described in the prior section to explain how Agile teams perform. The connection between Agile teams and distributed teams can be described by the following concept map:

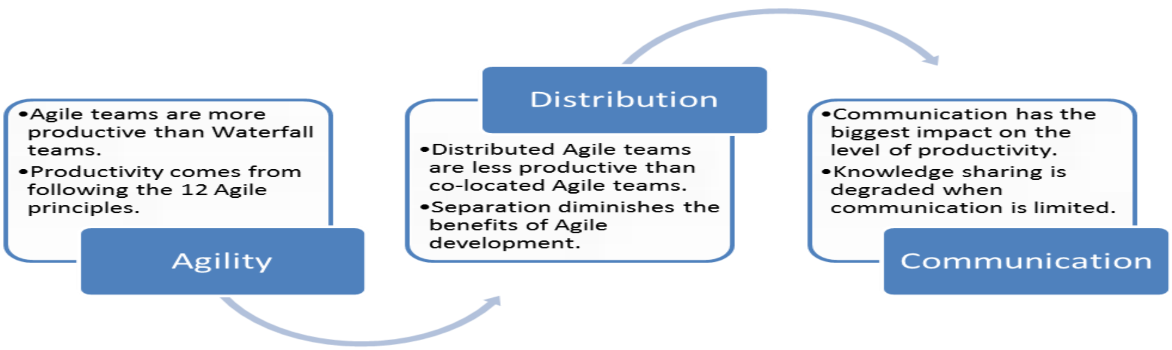

Figure 1 Literature Review Concept Map

The following research explains how the produtivity gained by practicing a pure Agile methodology is then deminished when teams are distributed, either geographically or by time zones, and how communicaiton plays the biggest role in this diminshed productivity. The following sections describe the literature documenting each concept in more detail.

Agility. Across many industries, there have been studies tracking the practice of the Agile methodology in software development while attempting to explain why Agile is gaining a significant foothold over more traditional methodologies (Rigby, et. al., 2016). The rationale for organizations to adopt Agile development methods is largely due to the perceived benefits. A recent study by Serrador and Pinto (2015) explained which benefits managers found when switching to an Agile practice. The pair of researchers surveyed over 865 Agile project managers and found a statistically significant impact on all three dimensions of project success, when defined as efficiency, stakeholder satisfaction, and perception of overall project performance. While important for explaining why managers believe Agile is effective, the study was still largely opinion based, as they asked project managers to evaluate if their own projects were successful.

A Brazilian study of over 5,000 software developers found a similar result (Bermejo, et. al., 2014), where professionals were surveyed about using agile methods on their projects. The findings of the survey were that while Agile projects were considered successful by the respondents, the researchers could not conclude that agile practices alone contributed to the success measures. Similar to the Serrador and Pinto research, the results were also opinion-based, asking respondents to evaluate their own project success. Other research on the topic (Kautz, et. al., 2014) again leveraged opinion-based surveys to evaluate Agile productivity. All three research studies concluded that managers of Agile teams believe that Agile development leads to more productive results.

A more quantitative study conducted in the telecommunications industry, however, added a measure of objectivity to the results of whether Agile projects have higher success rates over more traditional waterfall projects. In a research study by Papadopoulos (2015), more than 100 telecommunication team members were tracked across a ten month project. The variables collected included quality, which was based on defect metrics, agility, which was based on story changes, and employee satisfaction metrics. The study concluded that the Agile methodology performed better than traditional Waterfall methodologies in large, distributed projects. While other studies question whether the Agile methodology had a truly compelling case for benefits (Špundak, 2014), Papadopoulos also noted improvements in quality and customer perception of the end product, and further noted that, by its nature, agile practices encourage better communication of team members. This finding concurs with the opinion of teams who have been practicing the Agile methodology for many years; a 2012 study confirmed that Agile practitioners still saw benefits from many of the practices and would recommend continuing with most of the 12 principles (Williams, 2012).

The way productivity is measured in projects following the Agile methodology is also an important distinction, which was noted in a literature review by Hernandez-Lopez, Colomo-Palacios, and Garcia-Crespo, (2013). The authors conducted a review of different productivity elements used to measure job productivity, as opposed to project productivity, so that managers could focus on the most effective elements necessary to improve productivity. They reviewed other studies to identify the technical factors, such as lines of code or function points, and the soft factors, such as team collaboration, culture, skill, and experience, to determine the factors most related to productivity. The authors concluded that most research to date was based on traditional productivity measures and did not consider quality as a factor; they proposed that they would need more study and possibly new research on newer inputs to job productivity measures. This information was relevant in that it described the need to utilize a more updated measure of productivity that includes quality.

Some organizations firmly believe that the Agile methodology has played a significant role in their productivity, especially for distributed development. A 2016 case study followed a company as it transitioned from Waterfall to Agile development, leveraging a globally distributed workforce (Gupta, & Reddy, 2016) with the project members distributed across locations in Germany, India, and United States. The study leveraged a questionnaire to determine team opinions about the transition. While not a quantitative evaluation, the team members indicated they felt they were indeed more productive and had specifically become more adept at building teams which were motivated, self-organized and independent in taking decisions. The relevance of the study was that even distributed teams realized a productivity improvement when practicing Agile methods, which encouraged better cross-team communication. A similar case study conducted in Norway and the Ukraine (Moe, Cruzes, Dyba, & Engebretsen, 2015) found similar positive results when practicing distributed Agile development.

Distribution. While some distributed Agile teams may be perceived as more productive than their traditional counterparts, the majority of research indicates that distributed teams are known to have a noticeable loss of productivity. As team members are separated either geographically or by time zone, research indicates their productivity appears to suffer. One of the earliest studies on distributed team productivity was conducted by Herbsleb and Mockus (2003), who found that distributed development adds to cycle time to deliver software, thus decreasing productivity. The researchers followed the interaction of two large development teams from a single company for eight months. The researchers analyzed time sheets and used questionnaires to quantify communication patterns. The study found that distributed teams do take longer, 1.5 to 2x longer, to complete tasks over co-located teams. They further found that distributed teams are usually bigger, and the larger the team, the more communication time required.

To understand why distributed teams take longer to complete their work, there has been additional research testing out different hypotheses. The following table describes the different primary reasons examined in scholarly journals for why distributed teams have degraded productivity:

Table 2

Productivity Factors

Productivity Factor	Impact on Distributed Teams
Team Building	Poor cross-functional communication
Task Coordination	Delay in coordination
Team Knowledge	Limited opportunities for knowledge sharing
Document Sharing	Delayed inter-site communication
Team Distances	Limited availability of synchronous communication

Each of these factors is described in the following research.

The first avenue of research targeted the ability for distributed teams to focus on basic team building skills (Daim, et. al., 2012). A qualitative study conducted at Intel Corporation concluded that the basic fundamentals of team building were still valid even on virtual teams. The researchers noted that global virtual teams in the study seemed to perform poorly in maintaining effective cross-functional communication and did not seem to profit from the benefits that should have been offered by having such a diverse group of nationalities. The research team did not explore further why teams were less effective at team building or what role the geography of team members may have played in promoting or inhibiting effective communication, which the study found was necessary for team building.

A different line of research around distributed teams has focused on the more tactical aspect of task coordination. One of the pioneering works on the topic of software task coordination was a study by Cummings, Espinosa, & Pickering (2009) where the research team explored the coordination delay for team members divided by spatial (geography) or time zone boundaries. The research questions all attempted to understand the role of coordination and how the delay in coordination activities affected project performance. The study was conducted using survey data from 675 project members across 108 projects in a multinational semiconductor firm. The results of the study indicated that even having a small amount of overlap in work hours was beneficial, and that time zone boundaries appear to be more difficult to cross with communication technologies than spatial boundaries. While the research indicated that time zone and geography separation had different impacts on productivity, it did not confirm which team geographic design had the most impact on productivity.

A 2014 similar study by Razzak and Ahmed (2014) focused on the challenges related to knowledge sharing encountered by developers on distributed Agile projects. The purpose of this research was to answer the question if it was possible to retain the benefits that agile practices provide with respect to knowledge management in distributed Agile projects. Their hypothesis was that to establish effective collaboration and coordination in distributed Agile projects, developers will need to adopt different types of knowledge sharing techniques and strategies. Consistent with more recent research on the topic (Schmidt & Meures, 2016; Sharma, Kaur, & Kaur, 2015), they found that knowledge sharing in distributed Agile teams was more challenging, due to factors such as communication difficulties, language barriers and cultural barriers.

An earlier study involving Espinosa and Herbsleb with a different research team (Espinosa, et. al., 2007) addressed how team knowledge affects coordination, and how this effect is influenced by geographic separation. Their study was collected from a large telecommunications firm in Europe, conducted through individual interviews with team members in England and Germany. The study found that shared knowledge within the team helped to offset some of the negative effects of geographic separation on coordination to tasks.

Again, the study concluded that there was a productivity loss when teams were distributed, but the data was collected largely through interview and not quantitative measures.

A more recent research project launched a three-year study in 2015 to understand how document sharing impacted the productivity of distributed teams (Kamaja, Ruohonen, & Ingalsuo, 2015). The study used interviews and surveys with four large multi-national companies with development organizations in Asia and Europe. The study's literature review indicated that companies using component-based development were especially dependent on the success in a) inter-site coordination; b) knowledge management, and c) communication channels. If document sharing tools were not effective at timely knowledge sharing, communication would be delayed. While the study was still ongoing at the time of this writing, it confirmed that inter-site coordination and communication are important elements in distributed software development.

An additional 2015 study by Espinosa, Nan and Carmel (2015), though, provides some of the clearest evidence to date about a possible reason for productivity loss of distributed teams. This research attempted to build upon prior research and determine in a controlled, laboratory experiment if there was an association between time zone distance and team performance, and whether time zone distance may influence team performance through communication patterns and exchange of information. The study was conducted with 264 college student participants, assigning to them a digital task, and asking team members to simulate low, medium, and high complexity tasks. Through experimentation, the team members simulated being distributed by various degrees of time zone overlap. The study concluded that time zone distance had a negative impact on team performance, but that impact was not as much related to the distance as it was to the team interactions, influenced by the distance, which caused performance impact.

This finding was particularly relevant in this research chain, as it indicated that the ability for team members to interact is a key element of distributed teams. Collaboration is an important component in Agile software development, and the Agile manifesto prescribes that the most effective communication method for Agile teams is to deliver information face to face (Binder, et. al., 2014). This finding would imply that distributed software development teams practicing Agile may have lower productivity than teams practicing traditional methodologies.

Conversely, a 2014 study by Estler, et. al. (2014) provided a different conclusion about distributed Agile teams. The research team conducted a case study to answer the question for distributed teams if it matters whether they practice an Agile or structured methodology. Collecting data from 31 companies and 66 projects developed in Europe, Asia and the Americas, the researchers found that regardless of the communication practices of the teams, the results of the study showed no significant difference between the outcome of projects following agile processes and structured processes, suggesting that the Agile methodology and structured processes can be equally effective for globally distributed development. The limitations of the study were that it was largely opinion based, and it defined success as simply completing the project assignment without respect to also meeting the projected schedule or cost of the project.

Communication. Several recent studies of globally distributed software development teams indicate they indeed appear to have a distinct disadvantage when attempting to practice the Agile methodology, primarily due to the impact of degraded ability for communication (Alzoubi, et. al., 2016). In multiple studies by the team of Alzoubi, et. al. (2015, 2016), one of the researchers, Gill, established the Gill Framework, which was used in the study to provide the ADOMS (Adapting, Defining, Operating, Managing, and Supporting) approach for designing an Agile enterprise. The paper confirmed that well established, globally distributed development

(GSD) teams face many challenges, mainly around communication. The cost of that communication was higher with GSD teams; they noted that teams which relied on significant cross team communication performed poorly as distributed project teams.

Across most of the studies on distributed teams or Agile productivity, communication emerged as an important theme (Dreesen, Linden, Meures, Schmidt, & Rosenkranz, 2016). When communication was inhibited, productivity suffers. The 2012 study by Alistoun and Upfold (2012) confirmed this conclusion. While the role of formal communication has been largely explored, these authors contended that informal communication played a critical but largely unexplored role in group achievement, group maintenance, and support of team goals. Informal communication was noted as largely occurring via face-to-face communication, and absence of this communication on a virtual team led to challenges in many areas, such as not having a common understanding of the team goals.

This prior research about communication is consistent with a more recent study by Bano, Zowghi, and Sarkissian, (2016), who contended that globally distributed teams were impacted by Conway's Law, which asserts that communication structures of organizations actually constrain the development of the products they develop. This law is more applicable to globally distributed teams since they are by design required to share information across different time zones and locations. By conducting a case study, the researchers validated prior research and literature, confirming both Conway's law in modern global software development, and the communication issues within these teams. The researchers noted that while teams have the availability to use modern technologies which enable global software development teams to more regularly communicate, the lack of face-to-face interaction was still an impediment.

While distributed teams have less natural ability to communicate synchronously, when team members overcome this barrier then productivity does improve. An important study by Cataldo and Herbsleb (2008) started with the premise that distances lead to problems in communication and coordination, and ultimately in performance. The pair of researchers used a case study to prove out their hypothesis about top performers in a company and their contribution to communication. Their research showed how a core group of developers became the liaison between teams in different locations. These developers participated in more communication and more cross-site communication; they were also the top performer and the most productive member on their team.

Prior to their research, the conventional wisdom was that formal roles were necessary for communication effectiveness. More recent research also suggests that communication happens better naturally and over time instead. In this 2008 study, when formal roles were assigned, minimal communication emerged. The study implication defied conventional wisdom about formally tasking someone with the communication role. The study found that this practice may limit others who also would normally share information; it may also cause team members to limit their expectation for their own role. Instead of everybody helping to share knowledge, team members may assume only those with the formal role should do so, thus limiting effective communication.

Other studies confirmed that regardless of the role played on the team, coordination and communication are key contributors to Agile project success (Bass, 2015). A study by Holzmann and Panizel (2013) found a positive correlation between project manager communication and team success. A similar study of open source developers found that there was a correlation between the social network of the leader or star performers on the team and the success of the project (Hossain & Zhu, 2009). The Cataldo and Herbsleb study implies that when communication effectively flows for a distributed team, team members successfully complete their tasks. While synchronous communication is consistently documented as a core need for distributed teams, these prior research studies did not determine if any level of synchronous communication helps, or if teams must work completely overlapping business hours with the same time zone boundaries to achieve synchronous communication benefits.

Communication Accommodations. Many researchers were cautiously optimistic about the ability for distributed teams to practice the Agile methodology, but most focused on the need for some type of accommodation in order to be successful (Shrivastava & Rathod, 2014). More recent research has emerged on the usefulness of communication tools as an accommodation in making Agile distributed teams more productive (Yagüe, et. al., 2016). A 2016 study conducted at a research facility in Helsinki and Madrid exposed participants to various types of communication tools, such as video conferencing, wikis, news feeds, software builds, instant messaging, or face-to-face meetings. Participants were asked to rate the usefulness of the tool. Tools which facilitated synchronous communication were found to be the most useful, implying that the timeliness of the communication was a factor in the value to the tool users.

A study by Wagstrom, Herbsleb, & Carley, (2010), however, found that having the opportunity for synchronous communication alone was not enough; the communication also had to also be targeted and meaningful. This finding was echoed in a research study by Quisenberry and Burrell (2012) on the impact of trust, communication and relationship building with virtual teams. They noted it was not enough to provide technology options for communications; it was also incumbent upon team leaders to supervise the quality of the communication between their virtual team members.

Other productivity factors. While communication activities remain the number one contributing factor to distributed team productivity, the literature indicates there were a few alternate suggestions for root cause of productivity variations between co-located and distributed teams which should also be evaluated. These additional factors have fewer research studies supporting them, but it is important to note they may require further study to determine their relevance. These additional factors include the impact of a team's sourcing strategy and the complexity of the team's work on their task productivity.

Sourcing has been proposed through various research studies as a possible productivity factor for distributed teams. The employment sourcing strategy for distributed teams is relevant because many distributed teams are comprised of contingent workers. Some studies suggest that companies have a bias toward their employee staff, and as a result managers may disregard the input and advice of their contract based staff (Barnwell, Nedrick, Rudolph, Sesay, & Wellen, 2014). Other research has focused on whether contingent resources perform a reduced amount or lower quality of work (Bidwell, 2009). A 2008 study found study found that compared to employees, agency temporary workers have more negative attitudes toward parts of their job, being less satisfied with pay, exhibit lower commitment to the organization, and were less likely to engage in extra helping behaviors (Broschak, et. al., 2008).

Studies around the impact of sourcing on productivity have largely relied on qualitative data to determine effectiveness of contingent workers. Additionally, many of the studies on the topic of sourcing included resources of all skill levels and did not isolate the study to highly skilled fields such as engineering, computer science, or mathematics. As a result, it was difficult to confirm that sourcing was indeed a factor in team productivity and more research was necessary to evaluate the impact of sourcing; therefore, sourcing was selected as a second productivity variable to be considered in this proposed research study.

A third productivity area considered in the study was the type of work provided to distributed teams. The impact of software complexity on productivity was the subject of a 2012 study (Zhan, et. al., 2012). The study was attempting to determine if there was a beneficial level of task complexity to optimize efficiency. The researchers studied 74 projects across teams using a variety of programming languages, leveraging participants from two different organizations, and measuring project characteristics and project outcome. Using quantitative data, the researchers expected to find that as complexity rises, productivity decreases; instead, they found that there is a minimum threshold of complexity needed for developers to feel engaged, so that tasks too simple may also not be productive.

The study was especially relevant to distributed teams, since much of the guidance around distributed teams has focused on giving these teams easier tasks which require less coordination. The study by Zhan, et. al., indicated that giving teams a moderately difficult task can drive team unity, as they work together to solve the problem. As a result of this line of research, task complexity was considered as a third productivity variable in this research study.

Positive aspects of team distribution. Many studies have been conducted on what organizations can do to improve virtual team productivity, but research also indicates that there are some unique positive opportunities with global virtual teams (Zander, Zettinig, & Mäkelä, 2013). Although virtual interaction of teams has been described as challenging due to delays in communication, this somewhat anonymous communication forum also can open new doors and opportunities for women and non-white males, who may excel as team leaders and be more accepted as important team members. While much of this paper has focused on the negative aspects of distributed teams, it is important to note the positive side of virtual teams and link those benefits to future research as well.

Summary of Literature Review

The productivity loss for geographically distributed Agile teams is an important topic. The impact of communication practices on distributed teams is well represented in the literature on the topic, but the impact of team organization specific to distributed Agile software development team productivity was an area needing to be explored further. Several team functions have been identified which are critical to success of the productivity of global virtual teams, including goal alignment, knowledge sharing, and task coordination. Practitioners have referenced the Media Synchronicity Theory, the Coordination Theory, and Conway's Law to explain the importance of communication on task coordination and knowledge sharing.

Several prior studies about distributed Agile team productivity in this literature review have relied upon opinion-based measures to gauge whether team practices were productive. Other studies in this review were found to use a classroom or laboratory setting, which led to important findings but were limited in that they did not replicate an actual work place task or team dynamic. A smaller number of studies in this review found that other variables such as sourcing or task complexity may also have played an important role in the productivity of distributed teams. Finally, most of these studies did not attempt to address whether all communication among globally distributed teams is impaired just by the separation of team members, or if the communication opportunity during the team's business day primarily impacts impairment. The purpose of this quantitative study was to determine if synchronous communication tools along with the opportunity to synchronously communicate can mitigate that impairment.

Chapter 3: Research Method

As noted in Chapter 1, the problem this study addressed involved the restricted communication patterns for distributed software development teams practicing the Agile methodology. When software development teams are separated geographically or by different time zones, they are unable to adhere to all twelve principles of the Agile manifesto, which describes the key practices of the Agile methodology (Batra, 2009). These teams are specifically unable to practice the sixth principle, which prescribes that the most effective communication for Agile teams is delivered face-to-face.

Because it is not possible for distributed teams to communicate face-to-face, many organizations have dismissed the Agile practice as not viable for distributed teams (Matalonga, Solari, & Matturro, 2013). Past literature focused on the productivity differences between distributed and co-located agile teams (Alzoubi, et. al., 2016; Cummings, et. al., 2009) but did not evaluate the differences in productivity based on the degree of geographic separation. This research project adds to the growing body of research about the Agile methodology by further exploring if synchronous technology and temporal pattern alignment of work schedules can provide the same productivity benefits which teams experience when practicing the Agile methodology in a co-located space.

This chapter will describe the quantitative research method used for comparing the productivity of software development teams with varying degrees of team member time zone separation. The method for extracting the data from a large financial technology firm will also be described, along with the specific data elements extracted. Finally, the calculations used to analyze the data in the study will be described, along with any study limitations or assumptions.

Research Methodology and Design

A quantitative study was conducted to measure the performance of Agile methodology software development teams by observing the number of story points each team was able to complete per cycle day. A quantitative study was selected to ensure that results were based on the same standard for productivity. A qualitative study based on opinions of the participants was rejected, because it could have a different standard for productivity, depending on the person completing the survey. Similarly, a mixed method study which would require experimentation was rejected, because the addition of an on-site researcher conducting research would potentially cause artificial behavior among team participants. A quantitative study collecting historical data assured that the findings were genuine and not influenced by knowledge of the study.

Quantitative data was used to measure an Agile software development team's productivity, which was defined for this study as their velocity to deliver a unit of work as measured in story points. The study tracked different temporal patterns of team member's work hours, to monitor the synchronous communication periods possible, and to identify if different temporal patterns affected team velocity. While many different productivity instruments to measure software teams have been developed, these methods can yield uneven results when measuring productivity across different technologies, industries, or software languages (Sudhakar, et. al., 2012).

Comparing teams to each other has also been problematic in prior research, since each team can have different skill levels of its members. Additionally, development teams work on various software languages with different levels of complexity; even teams using the same software language may have a different complexity standard from their peers. This research study focused only on teams practicing the Agile methodology and using a normalized estimating system for each task, which is defined as a story. The Fibonacci Sequence is often used in the Agile practice as an estimating measure of complexity ("SAFe 4.0 for Lean Software and Systems Engineering," n.d.). The organization in the study practiced scaled Agile across the enterprise, using a normalized definition of the relative value of a story point. With each team having a common definition of a story point, teams applied this definition to the work they were able to produce. Teams considered, then, the skill level of the individual team members, their availability during the work cycle, and the complexity of the work based on the coding language, the task, and the application upon which they are working.

Teams were selected from a large, multi-national technology company with team members spread across many countries; the President of the Operations and Technology division agreed to allow the company to participate in the study. Participants were from software development teams distributed across locations in different cities in North and South America, Europe, Africa, the Middle East, and Asia Pacific countries. Team members in the study represented four communication patterns: (a) teams with completely co-located members, (b) teams with members working in the same temporal pattern, (c) teams with members who have less than half of a business day or less than four hours of workday overlap, and (d) teams with members who have no time zone overlap during their business day.

Prior researchers on the topic of distributed Agile team productivity have conducted their research by using a questionnaire to solicit the opinion of the executive management team or project manager to gauge whether their team practices were productive (Saafein & Shaykhian, 2014; Sarker & Sarker, 2009). This approach leads to instrumentation differences from the respondents, making it difficult to compare productivity results across teams even within the same division or company. Other studies have used a classroom setting (Adya, Nath, Sridhar, &

Malik, 2008; Swigger, et. al., 2012), which led to important findings but were limited in that they did not replicate an actual work experience.

This research design leveraged a methodology design similar to the study conducted by Espinosa, Nan and Carmel (2015). The research attempted to build upon prior research and determined in a controlled, laboratory experiment that there was an association between time zone distance and team performance, and that time zone distance influenced team performance through communication patterns and exchange of information. The study was conducted with 264 participants, where 41% were male, 66.9% were college students, and 49.7% were under the age of twenty-two. Using a digital task, team members were asked to simulate low, medium, and high complexity tasks. Through experimentation, the team members simulated being distributed by degrees of time zone overlap, including 100% overlap, 66%, 33% and 0% overlap.

The study concluded that time zone distance had a negative impact on team performance, but that impact was not as much related to the distance as it was to the team interactions, influenced by the distance, which caused performance impact. A limitation of the 2015 study was that it was a controlled laboratory setting using a set of participants who were not culturally or age diverse; hence they did not fully represent geographically dispersed teams operating today in most organizations. This research expanded upon the Espinosa, et. al. research to include actual business users conducting software engineering tasks, but leveraging similar time zone distances used in the prior study.

Population and Sample

The population for this study came from a large, multi-national technology company practicing the Scaled Agile framework. The organization is made up of 8,000 software technology professionals, sourced from employees and contractors. The Project Management

Office (PMO) for the organization helped reduce this pool to only software development team members making up the various roles on a scaled Agile team. Teams with members eligible for the study were located in the United States, Canada, Brazil, Belgium, France, Ireland, the United Kingdom, Germany, the Czech Republic, Turkey, South Africa, Australia, India, Japan, China, Singapore, and Malaysia. Some teams were excluded if they were not practicing some form of Agile; others were excluded if determined to have team members not fluent in English, since any cross team communication could be impacted by their language skills. The development organization was made up of 32% US, 50% India, and 18% all other geographies. The development organization was comprised of 60% employees and 40% contingent resources.

Inclusion criteria for the study involved development teams from across the enterprise who participated in software development activities. These activities were only included if they began during the month of August, 2017. Additional inclusion criteria included only teams which completed their tasks within a twelve-week period following the date their task began.

Exclusion criteria involved teams who did not complete actual software development tasks during this period. Additional exclusion criteria involved teams who did not practice the Agile methodology. A third exclusion criteria was to eliminate teams who did not speak a fluent common language, which was typically English, across all team members participating on the team.

Step one of the Data Collection section describes in more detail the process used for including and excluding teams. Included teams were divided into four communication treatment categories, depending on the temporal pattern of team members. The four communication treatments are described in the following table.

Table 3

Communication Overlap

Communication Pattern	**Degree of time zone overlap**
The entire team communicates face-to-face.	100 % overlap
Team is distributed but has similar temporal pattern among team members.	~66% or more overlap, or more than half a business day
Team is distributed with less than half day of overlapping work hours among team members.	~33% overlap or less than half a business day
Team is distributed and has no business day overlap across all members of the team	0% overlap

The sample size included 200 randomly selected stories, with 50 stories from teams representing each of the four communication treatments. Teams were limited to contributing a small number of stories to the study, to eliminate an over representation of any specific team. The study data was evaluated with an f-test using an ANOVA one-way fixed effects study, comparing the each team's output by story. Assuming an alpha of .05 and a beta of .2 with a medium effect of .25, the number of participants, in this case team stories, to use in the study resulted in a sample size of 200 stories or 50 stories per treatment.

The strength of this study was that it evaluated communication treatments, which can impact software development productivity, while being indifferent to software language or skill level of the individual team members. Prior studies on productivity have leveraged survey data to determine productivity for distributed teams, but these studies did not leverage a quantitative standard across multiple teams. While they observed communication activities occurring and concluded that communication activities were important, they did not track the location of various team members to determine if the time of day available for team members to communicate appeared to have any impact on the team's output.

Materials/Instrumentation

For instrumentation, an archival data set from a software lifecycle management tool, CA Agile, was selected. The tool contained software tasks, estimates of work, and completion time. This data set contained all the variables necessary for this data study. The software development lifecycle (SDLC) management tool was considered an adequate measure of software development productivity, since the data fields available in the data set to study task productivity were consistent with an industry definition of productivity, which is output divided by man days (Sudhakar, et. al., 2012).

The use of this standardized SDLC instrument was selected to help ensure the reliability and validity of the research. The data in the instrument was considered reliable because the variables selected were all collected through a series of controlled values, including system populated dates and user data extracted from the corporate human resources database. The values of data related to estimated and completed work days from the month selected for this study were consistent with the range of values across other months extracted but not included in the study.

The entire organization in the study utilized a common software development tracking tool, CA Agile, and all teams estimated and completed their work assignments using this enterprise tool. The CA Agile tool tracked estimated story points and documented the lifecycle of a story, logging a timestamp when the team began work and a timestamp when the product owner or scrum master labeled a story as completed. The definition of a completed story in the enterprise being studied meant that the story had been validated and passed unit testing inspection with no observable defects. A story may still have defects found later when the code was integrated with other code, but in isolation the work appeared to be complete and accurate at the time it was time stamped as completed.

In addition to task data, a limited set of team member profile data was fed into the CA Agile tool from the company's human resource tool, Workday, and merged with the CA Agile tool team data. Profile information, such as the work location and team member's worker type of either contingent or employee were captured from the Workday feed into the CA Agile tool. While team member profile data was evaluated to determine team member categorization for the different communication treatments and sourcing variables, no personally identifiable information was stored either about the individual team members or the team name. Additionally, the team locations were grouped into communication treatments using a previously established study instrument (Espinosa, et. al., 2015) to increase validity of the study design.

Operational Definitions of Variables

The entire set of variables used in this study are defined as follows:

Task velocity. This variable was the dependent variable, which demonstrated the effect of introducing the independent variables. Task velocity was calculated as the sum of all story points completed during the multiple week study period, divided by the business days during the twelve-week period (Jahr, 2014). Weekends were excluded when counting available business days. Holidays were excluded from available business days only if they occurred in one of the team member's work geographies. Vacation days for various team members were not evaluated, as it was assumed the team accounted for team member outages when estimating the work.

Communication treatment. This independent variable was the nominal value of the four treatments, modeled after prior research (Espinosa, et. al., 2015), representing geographical distribution of the team members. Even if only one team member was located in a different location, each location was considered part of the team's geographic distribution and contributed to the temporal pattern. The four nominal values tracked are represented in the following table describing communication treatments based on the time zone overlap of participants.

Table 4

Communication Treatments

Code	Communication Treatment
F2F	Face-to-face communication entirely possible (100% overlap).
RT1	Real Time communication possible, but not face to face. Team works largely overlapping business hours. (67% overlap).
RT2	Real time communication possible, but only via less than half of a day of overlapping business hours. For the majority of the day, communication is via asynchronous methods (33% overlap).
ACO	Asynchronous communication only is possible. (0% overlap).

Sourcing. This independent variable is the nominal value for the sourcing composition (Fariñas, et. al., 2016) of the team. This study did not distinguish between domestic and foreign sourcing, since geography was considered in assigning the communication treatment. Three nominal values included E for employees, C for contingent workers, and M for mixed, meaning a team included both contingent and employee team members.

Task complexity. This variable was a moderating variable, as it had an additional impact between the dependent variable of task velocity and the independent variable of communication treatment. The complexity of each story was relative to the story points assigned by the team and based on the size of the work effort (Bird, Nagappan, Devanbu, Gall, & Murphy, 2009). Teams in the research used a normalized definition of story points, and no stories were included if they had estimated story points higher than 21, which indicated the team may not be practicing Scaled Agile. The SAFe® range of story points was 1, 2, 3, 5, 8, 13, 21. For this rating, then, low complexity stories were stories with points less than 5 and accounted for 60% of the study data; higher complexity stories were pointed at 5 or more and accounted for 40% of the study data.

Study Procedures

The first step of this study was to seek approval from Northcentral University's Institutional Review Board (IRB). The IRB application was reviewed and approved to proceed, as the study was determined to be not human subjects research, so the next step was to collect the data from the targeted organization. The data for the study was collected from a large financial technology company, Mastercard. The company agreed to participate in the study because they have a large and geographically distributed software development workforce, and they were interested in optimizing team interactions for distributed teams. The company was also well suited for the study because they began using a single enterprise-wide software lifecycle tool in early 2016 to support a Scaled Agile practice across the organization. This common tool facilitated the data collection needed for this study because the data format for every work task was identical.

Also important in the study was the additional data needed for the team profile, such as the sourcing composition of each team and the location of each team member. Again, Mastercard used a single human resource tool, which had already been joined with the software development lifecycle tool, so that the profile data about team members could be collected without having to query each team member through a survey. Team data stored for the research did not contain any personally identifiable information, and the team name was replaced by a randomly assigned unique identifier. The data was extracted for stories created from July through December 2017, with stories created in the month of August selected for the research. Only stories which completed within twelve weeks were eligible for the data extract. Teams did not have advance notice of the study, as any prior notice could potentially have influenced the results if teams wanted to appear as productive as possible during the research period.

Data Collection and Analysis

Data was collected via an extract from the CA Agile, which is an enterprise electronic software development tool used by Agile teams in the company. The tool contained data about the team participants and their work output. Data was collected and filtered in the following three steps, to prepare the candidate data for analysis.

Step 1: Extract and label candidate teams from the Agile tool. Teams were selected from the tool if they demonstrated development activity during the time period selected for study. To demonstrate activity, the team needed to have at least one completed story documented in the tool during the time period studied. Teams also needed to be practicing the Agile methodology as identified by this company's equivalent of a project management office (PMO), which oversees the software development practice for the organization. Teams which were practicing different methodologies, such as Waterfall, but still using the CA Agile tool to manage their work were eliminated from the extract. The development team languages used by team members in the study organization included Java, C, C++, Cobol, and SQL.

Since the CA Agile tool was used to manage work for more teams than just software engineering, only teams containing at least one resource from the Software Engineering job family were selected for the study. For example, teams working with Java may do more activities than build code; some teams supported software defect research or application environment engineering. This study was focused on comparing the teams conducting the software development practice only. Across the entire enterprise, there were over 23,054 human resources in the CA Agile tool. Using the described criteria, the PMO eliminated non development teams, leaving a pool of 2,781 qualifying resources for this study. Another 494 resources were eliminated because they came from development teams but were not participating in software development activities; these eliminated resoures were working on other software development activities, such as building infrastructure or creating test criteria. This final refinement left a pool of 2,287 eligible team resources spread across 417 teams.

Data in the following table describes the data which was extracted in step one to help determine eligible teams who should be included in the research. Information about each team member from the pool of possible teams was initially extracted to provide the following information:

Table 5

Team Member Extract

Preliminary Data Collection Field	**Source**
Team Member ID	***Created during study****:* assigned using an anonymous, unique identifier created by the SDLC tool in place of team member's name
Team ID	***Created during study:*** assigned using a unique identifier created by the SDLC tool in place of team name
Team Member Work Geo: Country	***Extracted from CA Agile tool.***
Team Member Work Geo: City	***Extracted from CA Agile tool.***
Team Member Temporal Pattern	***Created during study:*** derived from geo country
Team Member Worker Type	***Extracted from CA Agile tool.***
Team Member Job Family	***Extracted from CA Agile tool.***
Team Member Work Division	***Extracted from CA Agile tool.***

Based on the location of the study participants, their work location was used to determine their temporal pattern, which indicated their ability to communicate synchronously. Teams were assigned the same temporal pattern if they were working in geographically similar countries where a common business day of roughly 9am to 5pm local time could overlap by at least six hours. Temporal patterns were separated into the following groups:

Table 6

Groups and Countries

Group	**Countries**
Group A	Containing team members located in North or South America countries (US, Canada, Brazil).
Group B	Containing team members located in western Europe (UK, Ireland, Germany, France), Turkey, Czech Republic or South Africa.
Group C	Containing team members located in Asia Pacific countries (India, Japan, Singapore, Malaysia, China, Australia).
Excluded	Team members located in a geography not included in Group A, B, or C.

A sample of the data extracted is shown in the following table:

Table 7

Sample Data from Step 1

Study Gen. Member ID	**Study Generated Team ID**	**Work Cntry**	**Work Office Location**	**Worker Type**	**Job Family**	**Division**	**Temp. Group**
20928	91962324828	US	Atlanta, Georgia	Empl.	Consultant, Software Engineering	Data Warehouse	A
30824	55146310240	US	Atlanta, Georgia	Cont.	Contract Worker	Billing	A
60235	84947907768	India	Bangalore	Cont.	Contract Worker	Processing	C
44863	55037513940	India	Bangalore	Cont.	Contract Worker	Billing	C

Step 2: Aggregate team data and assign study treatments. Team data was next summarized from information about individual team members and aggregated or calculated into information about the team. Using the following table, teams were assigned to one of the following communication treatments based on their time zone overlap period, which was represented by the temporal pattern collected in Step 1. Based on the work countries of teams considered for the study, three different geographic groups were considered: Group A, B, or C.

Table 8

Treatment Groups

Group	Communication Treatment
F2F	All team members have the same office location, as identified by the city in the Office Location field of the worker.
RT1	All team members have the same work country, or are assigned to the same temporal pattern group as follows: Group A: US + Brazil + Canada or Group B: Europe + Africa + Turkey + Czech Republic or Group C: India + Malaysia + Japan + Singapore + China + Australia
RT2	All team members are only in the following combination of temporal pattern groups: Groups A + B or Groups B + C
ACO	Any combination of workers on the team from both Group A and Group C

If any team had a member in an excluded geography, the entire team was eliminated from the study. The previous table described the combinations of temporal pattern groups which were used to calculate the communication treatment possible, based on team geography.

The following table describes how the sourcing treatment was assigned to each team:

Table 9

Sourcing Codes

Code	Sourcing Treatment
E	Employee Sourcing Only. Calculated from: number of Employee workers > 0, number of Contingent workers = 0
C	Contingent Sourcing Only. Calculated from: number of Employee workers = 0, number of Contingent workers > 0
M	Mixed Sourcing. Calculated from: number of Employee workers > 0 and number of Contingent workers > 0

The following tabular data was then collected about each team:

Table 10

Team Data Extract

Data Collection Field	Source
Team ID	***Derived in Step 1***
Number of Employee Team Members	***Created during study:*** count of the number of team members collected in step 1 with a worker type of employee.
Number of Contingent Team Members	***Created during study:*** count of the number of team members collected in step 1 with a worker type of contingent.
Sourcing Treatment	***Created during study:*** computed from number of employee and contingent workers using the Sourcing Code Table
Communication Treatment	***Created during study:*** derived from temporal pattern and team member work geo city collected in Extract 1.

When merged with the data from Step 1, the following extract shows a sample of the team data collected for this study:

Table 11

Sample Data from Step2

Study Generated Team ID	**Sourcing Treatment**	**Number of Employees**	**Number of Contingent Members**	**Communication Treatment**
82363060704	M	5	2	RT1
67643829272	M	10	5	F2F
99736580028	E	3	0	F2F
92741638340	M	2	5	F2F
76946621444	C	0	5	RT2
47457676322	M	4	3	ACO

Step 3: Extract eligible Agile stories for the study. Using the CA Agile tool, only completed stories were considered for inclusion, based on tasks assigned to teams selected in step 1. Each story was assigned a unique identifier. Only stories completed within twelve weeks of the story creation date were eligible for the extract. The following data elements were additionally extracted:

Table 12

Story Data Extract

Data Collection Field	Source
Story ID	***Created during study:*** assigned using a unique number generated by the SDLC tool.
Plan Estimate	***Extracted from CA Agile tool:*** estimated story points for the task.
Story Creation Date	***Extracted from CA Agile tool***
Story Accepted Date	***Extracted from CA Agile tool***
Team ID	***From Step 1***
Sourcing Mix	***From Step 2***
Communication Treatment	***From Step 2***
Cycle Days	***Created during study***: calculated as story accepted date minus creation date, plus 1. Holidays and weekends were not counted.
Cycle Velocity	***Created during study:*** calculated as estimated story points divided by cycle days. Also referred to as "story points per day".

No business details about the content of the stories or the business purpose were extracted when the data was appended to the data from prior steps. When merging the data from step 2 with the story details, a sample of the team data collected is represented in the following table:

Table 13

Sample Data from Step 3

Story ID	Plan Est.	Creation Date	Accepted Date	Team ID	Src Mix	Comm Group	Cycle Days	Cycle Velocity
S247678	5	08/02/2017	08/18/2017	47457676322	M	ACO	11	0.45
S247679	3	08/02/2017	09/19/2017	47457676322	M	ACO	31	0.10
S247472	8	08/01/2017	09/07/2017	52866336990	C	ACO	24	0.33
S247525	2	08/02/2017	09/08/2017	52866336990	C	ACO	25	0.08

The total population of stories in the extract month of August 2017 included 6599 total stories. The targeted sample population was 50 stories for each communication treatment, with 200 stories in total. To select the stories, the data was sorted by story id, which was a randomly assigned number. The first 50 stories from each communication treatment category meeting the criteria were selected for the study. Story complexity was derived from the plan estimate data, grouped by stories less than 5 points or greater than or equal to 5 points.

Analyze the Data. The dependent variable in this study was the team's story velocity. The independent variable was the communication treatment. The moderating variables were story complexity and team sourcing. There were three tests of the different variables collected for the research.

Test 1: One-way ANOVA of communication treatment. Using the mean value of the cycle velocity for each of the four communication treatments, the study tested the null hypothesis of $H_0 = \mu_1 = \mu_2 = \mu_3 = \mu_4$.

Test 2: One-way ANOVA of task complexity and communication treatment. Using the mean value of the cycle velocity for stories rated as high or low complexity, the study tested the null hypothesis of $H_0 = \mu_1 = \mu_2$ comparing overall complexity, and then $H_0 = \mu_1 = \mu_2 = \mu_3 = \mu_4$ against each of the four communication treatments based on complexity level.

Test 3: One-way ANOVA of team sourcing. Using the mean value of the cycle velocity for teams made up of employees, contingent, or mixed sourcing, the study tested the null hypothesis of $H_0 = \mu_1 = \mu_2 = \mu_3$ comparing overall sourcing, and then the same test within each communication treatment.

Assumptions

The study was conducted using data about software engineers from a large pool of development teams at a global technology organization. The researcher made a few basic assumptions of the teams being studied. The assumptions associated with this study are summarized in the following table, along with the rationale for the assumption:

Table 14

Research Assumptions

Assumption	Rationale for the Assumption
All teams in the study are comprised of competent software developers.	While some individual participants in the study may achieve different performance levels than their teammates, the study was reviewing team results and not the results of individual participants. Team members were assumed to compensate for the differentiated work capacity of each team member when assigning a work estimate.
Some teams may have a few members with outstanding or lesser skills.	Similar to the first assumption, there may be a few team members with outstanding or degraded performance, but their results were factored into the task estimate.
All teams were equipped for success by assigning them tasks they could reasonably and competently complete.	Teams were assumed to have been given tasks in good faith by their management team which were possible to complete and where they had all the resources necessary to complete the task.

Limitations

In addition to the above assumptions, this research had some limitations related to the type of development being studied. The research was limited to software development teams practicing the enterprise Agile methodology and using a normalized Agile estimating process. The results may have a different implication for organizations practicing other software development methodologies. Even teams practicing Agile could be interpreting the Agile methodology differently, which could potentially influence their results. While these differences are a concern, a 2014 study by Estler, et. al. (2014) showed that the differences in outcome between agile or structured methods may be negligible for distributed teams. The research team emphasized that methodology alone is not a determinant of project success and should not be used in isolation to make a decision about how best to manage distributed global teams. Even though a single methodology was studied in this research project, the research by this 2014 study indicates that variations on usage of the Agile methodology might not have a significant impact on team productivity.

Delimitations

The study was limited to an extract of the time frame of three months of data, to limit the transience of team members. As team members enter and leave a team, the team's ability to honor their previous estimates and their work productivity in general is negatively impacted (Jawadi, et. al., 2013). New team members change the team dynamics and require time to forge a team bond necessary for productivity, but this study did not attempt to quantify each team member's time on the project. Instead, the study was limited to a brief calendar window to minimize the change in the team member profile.

Ethical Assurances

There were no apparent ethical issues with the data collection or participants studied in this research. This research leveraged the key elements described in the Belmont Report of beneficence, respect for persons, and justice (United States, 1978). As a result, every effort was made in the collection of this research data to ensure that the data collected was kept safe and team member data included in the extract was removed.

The key concern with the data being extracted was to ensure that the reputation of the team members studied would not be harmed by the research. For that reason, any information which could personally identify an individual, their team name, or their work activity was removed and substituted an anonymous identifier. This replacement occurred before the data was exported for this study. The original data was secured in the encrypted database storing the lifecycle details, and the extracted data was stored on an encrypted hard drive until the data was updated with anonymous identifiers and exported out of the company for this research. Once the data was exported, the original extract of data was destroyed.

The team identifier was a unique number created by and stored in the CA Agile tool and is not the team id recognized by or available to users of the tool. Since team members were selected from teams across different locations, this privacy approach would support even more stringent privacy requirements of other counties, such as those in the European Union or Australia. The goal of this research was not to compare or judge the productivity of individuals but to measure the aggregated team results.

Team members were not interviewed for this study, since individuals may have been reluctant to share details about their work for a variety of reasons. In the study by Estler, et. al. (2014), team members who were interviewed in person by the research team were reluctant to share information about project success. The researchers did not collect additional data about this reluctance and could only speculate why team members were providing evasive answers. The researchers speculated that it was uncomfortable for team members to talk about failures either for personal reasons or for fear of reprisal from their management.

For these reasons, this study did not collect the data in person, and the participant’s name or other personally identifiable data were also not collected. This elimination of individual identifiers also ensured that participants were selected in an unbiased manner. Since the purpose of the research was to assist organizations to find practices which enable team members for success, putting respondents at employment risk would be reckless. For that same reason, even adding an independent observer in the company was unlikely to be accepted by the company's management or legal team, and would potentially cause artificial behavior among team members. To ensure that knowledge of the study would not drive artificial team behaviors, data was collected from recent historical projects.

As noted earlier, all data describing an individual, team name, or their work activity was removed and replaced with an anonymous identifier. While the research did not directly involve consent from human subjects, getting Northcentral IRB (Northcentral University, February 2017) approval was still completed to assure all key considerations in the ethical treatment of the research participants had been evaluated. Similarly, since the business nature of the projects was not extracted, there was no company-sensitive data or competitive data stored as well. To ensure that all privacy laws were observed related to the participants in different geographies, though, the company's legal counsel was consulted before collecting the data. Inclusion in the study was based on team geographic distribution and not individual member attributes, which also helped avoid selection bias. Inclusion of tasks was based on completed tasks only,

For the proposed research project, the researcher did not receive research funding from the hosting organization, nor did they fund the researcher's doctoral studies, but the researcher was an employee of the organization at the time of the study. To remove any appearance of a conflict of interest related to the collection of software development performance metrics, the researcher held a role which was not directly responsible for software developers included in the study while the research was being conducted.

Summary

This study utilized a quantitative design, extracting data from an enterprise wide software development lifecycle tool to measure the productivity of distributed teams across various tasks. Using a population of team members from countries across North and South America, Europe, Africa, Asia and Australia, four key variables were calculated or assigned to study task velocity, communication treatment, sourcing treatment, and task complexity. The data extract process involved replacing personal data or team data with unique, anonymous identifiers, to ensure the ethical treatment of the subjects being studied. The study was limited to teams practicing the Agile methodology at an enterprise level for software development tasks.

Measuring productivity of software development is a recommended practice for organizations (Sudhakar, et. al., 2012), but different instruments used to measure productivity across diverse teams have made achieving this goal challenging. Most studies on the topic have depended upon anecdotal data or did not attempt to quantify actual task-level metrics. For example, a study by Herbsleb & Mockus (2003) to analyze software development productivity reviewed time sheets of developers and used questionnaires to determine communication practices; however, the researchers assumed time spent on the end-to-end project was indicative of productivity. There can be many reasons why projects get delayed, so a metric focused on tasks and independent of the start-stop-start nature of a project is more accurate. For that reason, a research study such as this one, based on a quantifiable metric of task productivity can provide valuable insight to the research community.

The intent of this study was not to determine if individuals were effective on a team but to determine if the team itself was productive based on their communication patterns. With the appropriate precautions in protecting the anonymity of the project team and team members, and by collecting actual task performance metrics along with information about team member location, users of this research can more accurately define the elements needed to empower distributed teams for success. Project leaders may not always be able to influence the skill level or location of their team, but this research was intended to help them understand how to extract the most productivity possible from the team which has been assembled.

Having a large and diverse enterprise with a common data repository and common methodology is possible in only a small number of large technology companies. Finding such a company willing to share their data is also of great interest to the organizational research community of scientists. Sharing the details of the data extracted can be of benefit to other studies which may additionally be able to use the data for a different result or as the basis for their own future study.

Finally, the data and study results may be useful to help organizations create training or organizational structures which most facilitate virtual team effectiveness. A 2015 study on virtual teaming and digital learning (Andert & Alexakis, 2015) found that use of a training course could indeed encourage collaboration and teamwork. The implications for this research are that if organizations can identify factors which most enable productivity of virtual teams, and those factors are related to collaboration opportunities and team design, then improved team effectiveness can be facilitated through work structure and training of team members to leverage those factors.

Chapter 4: Findings

The purpose of this quantitative study was to study the problem of reduced productivity levels for teams practicing the Agile methodology when team members are distributed by geography or time zone. Specifically, it was unknown if there are organizational factors which can improve the productivity of these distributed development teams. The study was designed to answer the research question regarding whether any amount of separation of team members impacts productivity, or if various degrees of time zone overlap allows for sufficient synchronous communication to overcome the communication lag inherit with having distributed teams. The two additional variables studied were designed to answer the research questions regarding the impact of sourcing and task complexity on distributed team productivity. This chapter will describe the findings of the research conducted to study these three research questions. The research question and related null and alternative hypothesis used in the study are presented.

Validity and Reliability of the Data

The validity and reliability of the data for this study depended on the accuracy and consistency of the information recorded in the tool used for data capture and size of the population available for the study. The data used in this study came from an industry recognized software development lifecycle tool, CA Agile, which was used by Mastercard's Operations and Technology organization. The tool helped control the validity of the data, since only the task estimate could be keyed in by the resource team. Data about team members was loaded into the tool based on a feed from another source of truth at Mastercard, their human resource tool, Workday. Dates and times were systemically logged by the tool based on a US Central Standard timestamp and captured when certain activities were logged. The data extract from these toolsets, then, was considered valid, but ensuring reliability required additional filtering.

To ensure reliability of the data, the time period for the study was limited to tasks all started in the month of August 2017 and included only tasks which completed within twelve weeks, to minimize the amount of change which could occur on a software team and which could also impact the productivity of the team. The initial data set included all tasks, identified as stories, created from July 1 through December 24, 2017. This data included 276,912 stories. The same data extract from August 2017 was used for each analysis, to ensure the data reliability was not influenced by other factors, such as studying a significantly different set of team members. The study leveraged an independent ANOVA instead of a repeated measures ANOVA, since this was a historical data study and there were different team members studied across the different communication treatment groups.

The first challenge to reliability was to ensure the study did not compare non similar teams. To increase reliability, the study limited the analysis to teams practicing Agile software development, and excluded teams from other disciplines such as network operations or customer support. Once non development teams were eliminated during data step two, as described in Chapter 3, and the stories were limited to those which were ultimately completed, the list was reduced to a population of 126,894 stories.

A second challenge to reliability was to ensure the study compared teams which were practicing different software development methodologies. Although all the development teams in the study were encouraged to practice Agile, some had story point estimates well outside the norm of the Fibonacci scale, indicating they may not truly practice Scaled Agile. Removing these teams which did not appear to practice Scaled Agile further reduced the story population to 108,764 candidate stories.

The availability of sufficient data was a third important factor in reliability. The months of July, August, and September were initially reviewed, and each month had a similar number of stories created during the month, with July containing 7,824 stories, August containing 6,599 stories, and September with 5,650 stories. Holidays were also omitted from the count of business days possible if they were a non-work day for any team member. There were 11 global holidays in August, 12 global holidays in September and 8 global holidays in October recognized by the organization studied across the locations included in the research during the 12 weeks studied.

A fourth impact to reliability would be the impact of team transience. The month of August was ultimately selected to study, since teams largely followed quarterly release planning and August was the middle month of the quarter. Team transience was more likely to occur at the start of a quarter, so selecting the middle of the cycle gave teams more time to work together before measuring their results. Earlier studies by Adya, et. al. (2008), and Cummings, et. al. (2009) found that the soft factors of team productivity such as building team trust need time to evolve, so the introduction of a new team member requires some acclimation time. While this study did not attempt to evaluate the impact of individual team members coming and going, keeping the study period brief was one way to limit the impact to productivity based on changes in team dynamics.

Results

There were three primary research questions about team productivity which were studied in this data analysis. Each question's data set was evaluated using a one-way analysis of variance, also known as an ANOVA test, to compare differences between variable groups and evaluate if the differences were statistically significant. The significance threshold was set at .05 for each test. The data used in the study can be found in the appendix.

Question one: impact of communication treatments. The first research question studied involved the impact of different communication treatments which were categorized from the location of all the team members. The question was:

> **Q1** Amongst Agile software development teams using information communication technology tools, to what extent, if any, does the ability for various periods of synchronous communication during the work day impact team productivity?

The null hypothesis was that there would be no difference in team productivity based on team member location, while the alternative hypothesis would expect there to be some differences:

H1$_0$: There is no significant difference in task velocity rates for distributed and co-located teams.

H1$_a$: There is a significant difference in task velocity rates between teams which are co-located, distributed with similar temporal patterns, and distributed with mixed temporal patterns.

Using the mean value of the cycle velocity for each of the four communication treatments, the study tested the null hypothesis of $H_0 = \mu_1 = \mu_2 = \mu_3 = \mu_4$. The four communication treatments studied included face-to-face teams with 100% real-time communication possible (F2F), real-time communication possible with more than half a day of overlapping business hours (RT1), real-time communication possible but less than half a day of overlapping business hours (RT2), and finally teams with no overlap of some team member during their business hours, allowing asynchronous communication only (ACO). Fifty stories were extracted with the following results:

Table 15

Communication Treatments Results

Groups	Count	Sum	Average	Variance
F2F	50	53.20794	1.064159	1.313273
RT1	50	48.75321	0.975064	1.72648
RT2	50	42.21748	0.84435	0.778461
ACO	50	16.25262	0.325052	0.096783

The results of the one-way ANOVA returned a significant effect of communication treatment on task productivity ($F_{3,196} = 5.58$, $p < .05$). The F Value was greater than 1, indicating the sample means differ more than one would expect if all the population means were equal. Based on a P value of .05, the study found a significant relationship between communication treatment and team productivity, indicating the null hypothesis should be rejected because the difference is statistically significant. The following table shows the results from that analysis.

Table 16

ANOVA Results for Questions 1

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	16.39754	3	5.465848	5.584524	0.001073	2.650677
Within Groups	191.8348	196	0.978749			
Total	208.2324	199				

The results ratify findings in prior research (Yagüe, et. al., 2016) about the importance of synchronous communication to productivity. As expected, the null hypothesis was rejected and the data analyzed showed the highest number of story points per cycle day for the teams which were completely co-located and the lowest cycle velocity for teams with no temporal overlap.

The difference between the communication treatments was also of interest. When comparing the different communication patterns between each other, the results were as follows:

Table 17

Differences between Communication Groups

Comparing between groups	SS	df	MS	F	P-value	F crit
F2F & RT1	0.198445	1	0.198445	0.130567	0.718623	3.938111
RT1 & RT2	0.427159	1	0.427159	0.341053	0.560564	3.938111
RT2 & ACO	6.741738	1	6.741738	15.40539	0.000161	3.938111
F2F & RT2	1.207902	1	1.207902	1.154929	0.285158	3.938111

When comparing F2F and RT1 patterns, the F Value was less than one, and the P Value was greater than .05 ($F_{1,98}$ = .131, p =.719), so the effect of communication treatment was not considered to be significantly different when teams were face to face or working very similar business hours. The same comparison occurred between RT1 and RT2, with the communication treatment of more than half a day and less than half a day overlapping hours also demonstrated no significant effect on productivity. When comparing F2F and RT2, the F Value indicated the variation between the two samples had some significance ($F_{1,98}$ = 1.15, p = .285) but the P value indicated the effect was not statistically significant.

The most significant effect was demonstrated when comparing the temporal patterns of RT2 and ACO ($F_{1,98}$ = 15.41, p = .0002). Overall, the study results indicated when teams had the ability to synchronously communicate for any amount of time during their business day, the difference between their productivity levels was minimal. The biggest difference in productivity could be seen between teams with any amount of synchronous communication and teams having no synchronous communication amongst team members.

Question two: impact of task complexity and communication. The second research question reviewed whether task complexity also played a role in productivity on an Agile project. The question was:

Q2. How does the level of task complexity impact the productivity of teams practicing distributed Agile, with various degrees of geographic separation?

The null hypothesis expected there to be no difference in team productivity based on the complexity of the work, as identified by the size of the effort in story points. The hypothesis were formed as:

$H2_0$: There is no significant difference in task velocity rates for tasks of different complexity for teams, regardless of their team member location.

$H2_a$: There is a significant difference in task velocity rates based on task complexity, between teams which are co-located, distributed with similar temporal patterns, and distributed with mixed temporal patterns.

Stories were broken into high complexity stories, meaning those with five or more estimated story points, and low complexity stories, meaning those under five story points. Using the mean value of the cycle velocity for only stories rated as "high" complexity, the study tested the null hypothesis of $H_0 = \mu_1 = \mu_2$. The study then further tested the null hypothesis within low or high complexity stories of $H_0 = \mu_1 = \mu_2 = \mu_3 = \mu_4$ using each of the four communication treatments. The different distribution values for each communication type can be found in the following table.

Table 18

Task Complexity By Communication Treatment Results

Groups	Count	Sum	Average	Variance
ACO High	13	4.391285	0.337791	0.045134
ACO LOW	37	11.86133	0.320577	0.116608
F2F High	8	19.08889	2.386111	4.845035
F2F Low	42	34.11905	0.812358	0.336383
RT1 High	15	28.56599	1.904399	3.810892
RT1 Low	35	20.18723	0.576778	0.374646
RT2 High	4	3.325	0.83125	0.379647
RT2 Low	46	38.89248	0.845489	0.822331

The first unknown in this study was whether there would be a difference in high complexity and low complexity tasks on an Agile project, since teams factor in complexity when they assign story points. While more complex stories would have higher story points estimated, they could potentially be worked with the same velocity as low complexity stories. That was not the finding of the review. The following table shows a significant effect of complexity on productivity overall when comparing complexity without regard to team location. Low complexity stories showed twice the throughput per day compared to high complexity stories.

Table 19

Overall Complexity Findings

Groups	Count	Sum	Average	Variance
High	40	55.37116	1.384279	2.987068
Low	160	105.0601	0.656626	0.470399

Table 20

ANOVA Results for Question 2

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	16.94335	1	16.94335	17.53777	4.237E-05	3.888853
Within Groups	191.289	198	0.966106			
Total	208.2324	199				

The F Value was significantly greater than one, and the P Value was also greater than .05 ($F_{1,198}$ = 17.538, p = 4.237), indicating the null hypothesis should be rejected. The results of the ANOVA test indicated complexity did have a significant effect on productivity. The next analysis was to determine if the same significance of complexity was true across all the different communication treatments.

The following table shows the outcome of the ANOVA test comparing low and high complexity within each temporal group. The data study shows teams with little or no synchronous communication options demonstrated very little variation in productivity between low complexity and high complexity stories, indicating complexity did not have a significant effect on teams which could not communicate synchronously. Conversely, teams with significantly more business day overlap showed the most significant effect of complexity impacting productivity, with F values such as $F_{1,48}$ = 16.746 well above one and P values much lower than .05 for the F2F and RT1 communication treatments.

Table 21

Between Group Complexity Analysis

Between Groups	SS	MS	F	P-value	F crit
ACO low and high	0.002851	0.002851	0.028872	0.86579	4.042652
F2F low and high	16.64341	16.64341	16.74565	0.000163	4.042652
RT1 low and high	18.50707	18.50707	13.44127	0.000615	4.042652
RT2 low and high	0.000746	0.000746	0.000939	0.975683	4.042652

A final test for complexity was to isolate low complexity results and compare the difference between communication treatments, and then repeat the test with high complexity stories. Again, the difference based on communication treatment alone was consistent with the results from question 1 and found a significant effect of communication treatment among low or high stories. When comparing the four communication treatments, both low ($F_{1,48}$ = 5.378) and high ($F_{1,48}$ = 3.716) complexity stories were found to have F Values well above one and P Values under .05.

Table 22

Complexity across Communication Treatments

Between Groups	SS	df	MS	F	P-value	F crit
Low	7.003947	3	2.334649	5.397706	0.001463	2.662196
High	27.54736	3	9.182453	3.71641	0.019948	2.866266

Question three: impact of team sourcing. The third and final research question around team productivity studied whether the sourcing of team members, either as employees, contractors, or a mix of both, would play a role in productivity on an Agile project. The question was posed as:

Q3. To what extent, if any, does the sourcing of an Agile team impact the productivity of teams with various degrees of geographic separation?

The null hypothesis was that sourcing would demonstrate no significant impact on productivity, while a limited number of prior studies indicated a resource's sourcing affinity could impact how hard they work on a project. The hypothesis was framed as:

$H3_0$: There is no significant difference in task velocity rates for teams comprised of different sourcing strategies, regardless of team member location.

$H3_a$: There is a significant difference in task velocity rates, based on team sourcing strategies, between teams which are co-located, distributed with similar temporal patterns, and distributed with mixed temporal patterns.

Using the mean value of the cycle velocity for teams made up of employees, contingent, or mixed sourcing, the study tested $H_0 = \mu_1 = \mu_2 = \mu_3$ across all locations. In this study, the null hypothesis was not rejected, indicating there was not a statistically significant difference in productivity based on sourcing alone across groups in a similar temporal pattern.

Table 23

Sourcing Results

Groups	**Count**	**Sum**	**Average**	**Variance**
Sourcing M	126	109.2694	0.867217	1.395158
Sourcing C	30	19.27894	0.642631	0.360354
Sourcing E	44	31.88294	0.724612	0.507581

Table 24

ANOVA Results for Question 3

Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	1.561368	2	0.780684	0.744153	0.476468	3.041753
Within Groups	206.671	197	1.049091			
Total	208.2324	199				

The results of the analysis showed an F Value less than one, which indicates the difference in the means of the study data were not statistically different any more than one would get by chance, so the null hypothesis should be accepted. When testing each communication treatment individually to compare the three sourcing categories, the results were not significant for any single communication treatment alone. Two treatments showed an F Value slightly higher than 1 but the P Value was well above .05, indicating the null hypothesis would not be rejected.

Table 25

Sourcing by Communication Treatment

Comm	Groups	Count	Sum	Average	Variance
ACO	M	39	11.89533	0.305008	0.090132
ACO	C	4	2.413333	0.603333	0.220489
ACO	E	7	1.943961	0.277709	0.052461
F2F	M	27	34.2	1.266667	2.131474
F2F	C	10	8.555556	0.855556	0.225103
F2F	E	13	10.45238	0.804029	0.373668
RT1	M	34	38.42187	1.130055	2.384515
RT1	C	9	3.748016	0.416446	0.036597
RT1	E	7	6.583333	0.940476	0.330357
RT2	M	118	107.0814	0.907469	1.458374
RT2	C	26	16.86561	0.648677	0.391266
RT2	E	37	29.93898	0.809162	0.551351

Table 26

Sourcing Analysis by Communication Treatment

Between Groups	SS	df	MS	F	P-value	F crit
ACO	0.34112	2	0.17056	1.82138	0.173038	3.195056
F2F	2.422084	2	1.211042	0.919111	0.405923	3.195056
RT1	3.633612	2	1.816806	1.054666	0.356406	3.195056
RT2	1.505221	2	0.752611	0.668954	0.513527	3.046721

Evaluation of the Findings

The results of the study indicate that geographic location does play a significant role in the outcome of team productivity. This finding is important because the basis for teams being able to practice the Agile methodology includes the requirement that teams should ideally be located face to face. The study indicates face-to-face teams indeed have a productivity advantage, but that any amount of synchronous communication overlap is still beneficial when teams are working together. The most significant productivity drop occurs when there is no opportunity for synchronous communication between all team members.

The study also found that task complexity or sourcing alone did not significantly impact productivity, but when in combination with synchronous communication availability, there was indeed some related impact. The communication treatment, however, more than the complexity of the work or the sourcing of the team members was found to be the more important variable.

The findings around communication treatments were consistent with the findings from a laboratory study by Espinosa, et. al. (2015). In the laboratory study, however, time zones were simulated and task were much shorter than real world activities. This study leveraged team members physically separated and actual work tasks which took days or weeks to complete. This study replicated the finding of the Espinosa study, which was that while distances matter when assembling team tasks, temporal distances have the most impact.

Also of interest in the study was the finding about the impact of sourcing. Teams made up of contingent resources performed similarly to their employee counterparts, and having contingent workers on the team did not show a significant effect on the work output for the team. In this study, mixed teams of both employees and contractors actually had the most productive results. The implication is that offshoring itself is not the factor which causes productivity loss, but when teams are offshore and have no overlapping communication opportunity, the temporal treatment is the more important factor in offshoring productivity. While this finding is consistent with other research, it does refute some prior studies (Bidwell, 2009) which indicated that contingent resources are less productive than their employee counterparts.

Summary

A series of one way ANOVA calculations were used to evaluate the quantitative data extracted for this analysis. Understanding the impact of temporal separation can lead to important organizational strategies for companies as they source resources globally. The impact of overlapping business hours on a team's ability to communicate was demonstrated in the productivity results of teams with varying degrees of temporal pattern overlap. Only teams with no ability to communicate synchronously showed a significantly different and lower productivity output. Other variables such as task complexity and team member sourcing were not found to show significantly different productivity results, outside of the temporal distance variable. The implications, recommendations and conclusions based on the findings of this study will be discussed in Chapter 5.

Chapter 5: Implications, Recommendations, and Conclusions

As companies leverage a globally distributed workforce and attempt to gain the benefits of Agile software development, a distinct productivity gap has emerged between co-located and distributed Agile teams, with co-located teams consistently delivering more productive results. Communication practices are most often noted as the reason for this productivity delta, due to the extensive coordination needs on an Agile project. Teams which are separated either geographically or by time zone experience different levels of coordination delay, which impacts their ability to complete tasks quickly and accurately.

The purpose of this quantitative research study was to determine which development team variables had the most impact on productivity for co-located and distributed teams. Based on prior theory and research, grounded in the Coordination Theory, the Media Synchronicity Theory, and Conway's Law, this research project was conducted to determine if the benefits of face-to-face communication could be extended through synchronous communication alignment. The hypothesis being tested was that the same productivity benefits of face-to-face communication could be achieved with adjustments in the time of day teams communicate, and with the availability of communication technology, such as instant messaging, video and audio conferencing, and online collaboration tools. This chapter will describe the implications from the findings of this research and how organizations may use this information to structure Agile teams.

Implications

The primary research question for this study was to determine among Agile software development teams whether the ability for various periods of synchronous communication during their work day impacted team productivity. This research question was based on the observation that collaboration tools available to team members could potentially simulate the benefits of face-to-face communication by providing other synchronous communication options. Secondary questions in this study involved the impact of task complexity and team sourcing as other possible factors for team productivity.

The results of the study were consistent with the theoretical framework and prior studies described in Chapter 2, which indicated that as teams were separated geographically, their productivity decreased. As the ability for synchronous communication time decreased amongst team members, lower productivity was expected from the team (Espinosa, et. al., 2015). This study found results consistent with the Coordination Theory and Media Synchronicity Theory, which indicates software developers must coordinate to distribute work among the team, and they must agree upon how that work will be approached. When their opportunity to communicate about this coordination and collaboration on the software design was decreased, it took longer to complete their assigned work. The study results found that team members who had the most opportunity to coordinate synchronously also had the highest amount of productivity. As team members became separated, physically and temporally, their ability to communicate was further reduced.

Based on the findings of decreasing productivity as teams are further separated by time zones, the implication for organizations is to assemble team members with as much overlapping business hours as possible. While being completely co-located showed the highest levels of team productivity, co-location is not always possible. When co-location is not an option for an organization, teams in this study indicated that teams can still show strong productivity results when they were able to communicate during the same business hours even if geographically separated. If having overlapping business hours is not possible based on the location of the resources available to an organization, the role of a coordinator who can work overlapping hours with the different team members becomes more important.

Some of the teams in the study straddled all three temporal groups, with team members in the United States, Europe, and South Asia. Only the team members in Europe would have had the ability to communicate naturally with their peers in both the US and South Asia. These teams were considered part of the RT2 communication treatment, where less than half a business day was naturally available to team members. Even still, these teams performed significantly better than teams with no synchronous communication options between team member locations.

While team member location was considered an important team attribute from the research, task complexity as an attribute had mixed results. One would expect task complexity was already factored into the team estimate of story points, so the productivity measure of story points per day should be relatively the same regardless of the complexity of a task. When looking at stories with higher story points assigned, however, teams who worked the most overlapping business hours showed a measurable velocity difference between stories with low or high complexity, while teams with little or no overlapping business hours showed almost no distinction in their velocity based on task complexity.

The implications around task complexity indicate the need for further study. The results do not mean that teams with less synchronous communication time performed their tasks faster. They simply performed more consistently between low and high complexity tasks. The teams with more synchronous communication time significantly outperformed low complexity tasks over high complexity tasks. These results indicate that team location still plays a role in productivity results, so organizations should still consider staffing teams with as many overlapping business hours as possible, regardless of the complexity attribute of the work.

The third and final attribute studied for team productivity was the sourcing attribute. The study evaluated whether teams made up of employees only, contingent workers only, or a mix of contingent and employee workers performed their tasks differently. The results of the study found that measuring team productivity based only on sourcing did not show significantly different productivity results. While a limited number of prior studies indicated that contingent workers were less committed to the organization's success and may be less productive (Broschak, et. al., 2008), those studies were not based on technology skilled workers. The implication of this study indicates that supplementing a team with contingent workers neither adds to nor takes away from productivity. A more important attribute for sourcing a team was found to be the location of team members.

Recommendations for Practice

This study was consistent with the research conducted by Espinosa, et. al. (2015), which shared that communication frequency and turn taking had positive effects on team production speed. A clear relationship between temporal distance and team performance was documented in the prior study, and a similar relationship was found to be true in this study. These findings indicate the importance for organizations to staff teams with as much overlapping work hours as possible for all the members of a team. Companies with team members in multiple geographies would be better served having all team members working in a single geography rather than dispersing a single team across more than one location. For example, instead of having two teams of 7 members, each with three members in the United States and four members in India, the organization would see more productive results with a team of six members in the United States and a team of eight members in India.

The challenge comes for organizations when the team members do not have fungible skill sets. It may not be as simple as reassigning teams if there are not enough skill sets in a certain geography to make a well-rounded team. As a result, organizations will also have to consciously recruit all the skills they need in each geographic location to see the highest level of productivity results from a team. For an agile team, it would mean hiring all the agile roles, such as scrum master or coach, system or business analyst, development engineers, and quality engineers all in the same general geography.

Recommendations for Future Research

The nature of this quantitative study was to review historical team outcomes, but it did not further investigate the type of team interactions which had the most positive impact on team productivity. The productivity findings correlating team member location with team output are consistent with other studies. An important extension of this study, then, would be to determine which communication tools or activities had the most positive impact on team productivity. Team members in this study had a variety of tools available to them, including online collaboration tools, chat rooms, and video and audio conferencing. The study did not attempt to quantify which tools team members used or to correlate results to the tool itself. Further research in communication techniques or tools would be of further interest to organizations which will need to support distributed teams and invest in collaboration technology for those teams. Such a study would require more in depth participation and monitoring of the team members studied and may be better suited for a university setting, where such a study would not disrupt an organization’s output or profitability.

Conclusions

The research questions and the purpose of the study were addressed through analysis of archival data capture of Agile team member locations and team development activity. The study was a review of Agile team productivity, based on estimated story points and the time the team spent to complete those stories. The study analyzed the historical results of of 2,287 eligible software development resources spread across 417 teams. The teams were grouped across three temporal areas, made up of 16 countries. A twelve-week period of tasks were extracted and evaluated for this research. The results using a one-way ANOVA statistical calculation showed significantly different productivity results for teams with limited or no time zone overlap in their business day, as compared teams which were completely co-located or had a high degree of time zone overlap amongst team members.

Distributed teams by their very nature will not have the same seamless communication benefits that onsite, co-located teams experience. Recognizing these communication differences and structuring team locations or team work shifts to encourage synchronous communication is an important way managers can mitigate the communication loss inherent to distributed teams. By managing team member assignment by location, organizations can effectively avoid or reduce the inherent productivity loss of virtual teams.

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Appendices

Appendix A: The Agile Manifesto

The twelve principles outlined in the Agile Manifesto (Batra, 2009, p. 146), are the following:

1. Our highest priority is to satisfy the customer through early and continuous delivery of valuable software.
2. Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage.
3. Deliver working software frequently, from a couple of weeks to a couple of months, with a preference to the shorter timescale.
4. Business people and developers must work together daily throughout the project.
5. Build projects around motivated individuals. Give them the environment and support they need, and trust them to get the job done.
6. The most efficient and effective method of conveying information to and within a development team is face-to-face conversation.
7. Working software is the primary measure of progress.
8. Agile processes promote sustainable development. The sponsors, developers, and users should be able to maintain a constant pace indefinitely.
9. Continuous attention to technical excellence and good design enhances agility.
10. Simplicity--the art of maximizing the amount of work not done--is essential.
11. The best architectures, requirements, and designs emerge from self-organizing teams.
12. At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behavior accordingly.

Appendix B: Site Permission Letter

Mastercard
2200 Mastercard Boulevard
O'Fallon, MO 63368-7263

tel 1-636-722-6100
www.mastercard.com

mastercard

November 13, 2017

Dear Northcentral University IRB:

On behalf of Mastercard Operations & Technology, I am writing to grant permission for Kimberly Martin, a doctoral candidate at Northcentral University, to conduct her research titled, "Study of Productivity Rates for Geographically Distributed Agile Teams". I understand that Kimberly will use anonymous data extracted from Mastercard's Application Lifecycle Management tool, and will export data about team geography, sourcing, and story velocity to conduct her data analysis. We are happy to participate in this study and contribute to this important research.

Sincerely,

Ed McLaughlin
President, Mastercard Operations & Technology

Appendix C: Study Data

Story ID	Plan Estimate	Creation Date	Accepted Date	Team ID	Sourcing Mix	Comm Treatment	Cycle Days	cycle Velocity (points per day)
S251619	1	08/09/2017 12:02 AM CDT	08/09/2017 01:52 AM CDT	46772663603	M	F2F	1	1.00
S247434	1	08/01/2017 06:07 PM CDT	08/09/2017 04:04 PM CDT	47457681609	E	F2F	7	0.14
S248327	1	08/02/2017 02:46 PM CDT	08/03/2017 03:39 PM CDT	47457681609	E	F2F	2	0.50
S247552	2	08/02/2017 12:52 AM CDT	08/02/2017 12:55 AM CDT	80329076012	E	F2F	1	2.00
S247553	1	08/02/2017 12:52 AM CDT	08/02/2017 12:55 AM CDT	80329076012	E	F2F	1	1.00
S248670	2	08/03/2017 05:08 AM CDT	08/08/2017 09:19 AM CDT	1.09785E+11	M	F2F	3	0.67
S247444	1	08/01/2017 06:20 PM CDT	08/01/2017 10:00 PM CDT	49074627229	E	F2F	1	1.00
S249296	1	08/03/2017 08:42 PM CDT	08/07/2017 10:59 PM CDT	49074627229	E	F2F	3	0.33
S246800	2	08/01/2017 04:25 AM CDT	08/01/2017 04:25 AM CDT	56879698122	C	F2F	1	2.00
S246804	1	08/01/2017 04:28 AM CDT	08/01/2017 04:28 AM CDT	56879698122	C	F2F	1	1.00
S248821	1	08/03/2017 10:17 AM CDT	08/04/2017 10:14 AM CDT	46772665237	M	F2F	2	0.50
S248823	1	08/03/2017 10:17 AM CDT	08/04/2017 10:13 AM CDT	46772665237	M	F2F	2	0.50
S248709	3	08/03/2017 07:26 AM CDT	08/07/2017 03:51 PM CDT	48620050247	M	F2F	2	1.50
S256002	2	08/16/2017 01:22 AM CDT	08/17/2017 12:46 AM CDT	48620050247	M	F2F	2	1.00
S246817	2	08/01/2017 05:00 AM CDT	08/03/2017 06:21 PM CDT	46772665760	M	F2F	3	0.67
S262630	7	08/28/2017 06:37 AM CDT	09/08/2017 04:37 AM CDT	46772665760	M	F2F	3	2.33
S248451	8	08/02/2017 08:18 PM CDT	08/07/2017 11:04 PM CDT	52122781240	M	F2F	4	2.00
S246767	2	08/01/2017 02:53 AM CDT	08/02/2017 08:29 AM CDT	62946263659	M	F2F	2	1.00
S247796	2	08/02/2017 04:57 AM CDT	08/05/2017 12:38 AM CDT	62946263659	M	F2F	3	0.67
S246982	1	08/01/2017 08:27 AM CDT	08/07/2017 08:34 AM CDT	74901022828	M	F2F	5	0.20
S248713	3	08/03/2017 07:42 AM CDT	08/07/2017 08:36 AM CDT	74901022828	M	F2F	3	1.00
S247003	3	08/01/2017 08:53 AM CDT	08/04/2017 01:14 AM CDT	1.04341E+11	E	F2F	4	0.75
S247017	3	08/01/2017 08:58 AM CDT	08/04/2017 01:14 AM CDT	1.04341E+11	E	F2F	4	0.75
S246930	3	08/01/2017 07:53 AM CDT	08/08/2017 09:37 AM CDT	46772663390	M	F2F	5	0.60
S247856	3	08/02/2017 05:42 AM CDT	08/08/2017 09:47 AM CDT	46772663390	M	F2F	4	0.75
S250760	2	08/08/2017 12:08 AM CDT	08/08/2017 01:43 AM CDT	49258164572	E	F2F	1	2.00
S247051	1	08/01/2017 09:26 AM CDT	08/01/2017 03:30 PM CDT	1.24317E+11	M	F2F	1	1.00
S248834	5	08/03/2017 10:31 AM CDT	08/03/2017 10:31 AM CDT	1.24317E+11	M	F2F	1	5.00
S247613	2	08/02/2017 01:21 AM CDT	08/08/2017 07:32 AM CDT	69051832984	C	F2F	4	0.50
S259992	5	08/23/2017 12:10 AM CDT	08/31/2017 03:02 PM CDT	69051832984	C	F2F	6	0.83
S247443	1	08/01/2017 06:19 PM CDT	08/01/2017 06:19 PM CDT	58134210865	E	F2F	1	1.00
S255425	3	08/15/2017 08:45 AM CDT	08/25/2017 02:38 PM CDT	49601009910	C	F2F	9	0.33
S258564	2	08/21/2017 08:27 AM CDT	08/24/2017 08:21 AM CDT	49601009910	C	F2F	4	0.50
S247889	2	08/02/2017 06:46 AM CDT	08/08/2017 06:41 AM CDT	46772663587	M	F2F	4	0.50
S248787	1	08/03/2017 09:15 AM CDT	08/08/2017 04:31 PM CDT	68583738100	M	F2F	4	0.25
S250274	1	08/07/2017 10:24 AM CDT	08/08/2017 03:00 PM CDT	68583738100	M	F2F	2	0.50
S248176	1	08/02/2017 11:11 AM CDT	08/04/2017 09:51 AM CDT	46772665776	M	F2F	3	0.33
S249058	13	08/03/2017 01:34 PM CDT	08/04/2017 09:52 AM CDT	46772665776	M	F2F	2	6.50
S266472	8	08/31/2017 11:45 AM CDT	09/20/2017 08:42 AM CDT	1.36014E+11	M	F2F	15	0.53
S246835	1	08/01/2017 05:35 AM CDT	08/07/2017 08:08 AM CDT	51203381728	M	F2F	5	0.20
S249059	2	08/03/2017 01:36 PM CDT	08/04/2017 01:27 PM CDT	46772666650	C	F2F	2	1.00
S250292	2	08/07/2017 10:40 AM CDT	08/10/2017 08:29 AM CDT	46772666650	C	F2F	4	0.50
S247448	3	08/01/2017 06:28 PM CDT	08/01/2017 06:28 PM CDT	59547467693	M	F2F	1	3.00
S247653	1	08/02/2017 01:46 AM CDT	08/06/2017 11:28 PM CDT	58151273138	E	F2F	3	0.33
S247086	2	08/01/2017 10:03 AM CDT	08/07/2017 02:59 PM CDT	55300161339	E	F2F	4	0.50
S256069	1	08/16/2017 03:59 AM CDT	08/24/2017 01:25 PM CDT	55300161339	E	F2F	7	0.14
S246766	5	08/01/2017 02:53 AM CDT	08/08/2017 08:12 AM CDT	50483399079	C	F2F	5	1.00
S251815	8	08/09/2017 02:20 AM CDT	08/22/2017 08:13 AM CDT	50483399079	C	F2F	9	0.89
S247985	1	08/02/2017 07:37 AM CDT	08/02/2017 11:16 AM CDT	46772663622	M	F2F	1	1.00
S248798	2	08/03/2017 09:29 AM CDT	08/04/2017 08:55 AM CDT	46772663622	M	F2F	2	1.00

Story ID	Plan Estimate	Creation Date	Accepted Date	Team ID	Sourcing Mix	Comm Treatment	Cycle Days	cycle Velocity (points per day)
S253529	1	08/10/2017 02:22 PM CDT	08/14/2017 03:47 PM CDT	82363060704	M	RT1	3	0.33
S256429	1	08/16/2017 11:09 AM CDT	08/17/2017 08:50 AM CDT	82363060704	M	RT1	2	0.50
S247111	1	08/01/2017 10:30 AM CDT	08/07/2017 03:58 PM CDT	82363060704	M	RT1	5	0.20
S257448	1	08/18/2017 04:18 AM CDT	08/23/2017 10:59 AM CDT	46772663823	E	RT1	4	0.25
S248748	5	08/03/2017 08:32 AM CDT	08/09/2017 05:25 AM CDT	46772663823	E	RT1	5	1.00
S257405	3	08/18/2017 03:54 AM CDT	08/31/2017 04:38 PM CDT	1.157E+11	M	RT1	9	0.33
S257406	3	08/18/2017 03:58 AM CDT	08/24/2017 10:24 AM CDT	1.157E+11	M	RT1	5	0.60
S266075	5	08/31/2017 05:01 AM CDT	09/15/2017 01:00 PM CDT	58067407017	M	RT1	12	0.42
S247120	13	08/01/2017 10:38 AM CDT	08/24/2017 08:09 AM CDT	58067407017	M	RT1	17	0.76
S248804	2	08/03/2017 09:45 AM CDT	08/03/2017 09:51 AM CDT	55145856544	M	RT1	1	2.00
S248302	5	08/02/2017 02:27 PM CDT	08/02/2017 05:45 PM CDT	55145856544	M	RT1	1	5.00
S249655	5	08/04/2017 09:23 AM CDT	08/04/2017 09:23 AM CDT	55145856544	M	RT1	1	5.00
S249759	2	08/04/2017 10:19 AM CDT	08/04/2017 10:19 AM CDT	54545420326	E	RT1	1	2.00
S251452	1	08/08/2017 02:52 PM CDT	08/10/2017 03:45 PM CDT	54545420326	E	RT1	3	0.33
S253059	5	08/10/2017 10:04 AM CDT	08/10/2017 10:04 AM CDT	54559125432	M	RT1	1	5.00
S253060	5	08/10/2017 10:04 AM CDT	08/10/2017 10:04 AM CDT	54559125432	M	RT1	1	5.00
S251476	2	08/08/2017 03:23 PM CDT	08/22/2017 10:16 AM CDT	57216788251	M	RT1	10	0.20
S265091	3	08/30/2017 05:21 AM CDT	09/08/2017 07:45 AM CDT	76946627960	C	RT1	8	0.38
S252171	5	08/09/2017 07:25 AM CDT	08/28/2017 07:01 AM CDT	1.18781E+11	C	RT1	12	0.42
S252179	8	08/09/2017 07:37 AM CDT	09/01/2017 03:42 PM CDT	1.18781E+11	C	RT1	16	0.50
S257441	1	08/18/2017 04:09 AM CDT	08/21/2017 03:48 AM CDT	54678709821	M	RT1	2	0.50
S256745	5	08/16/2017 11:19 PM CDT	08/22/2017 08:53 AM CDT	54678709821	M	RT1	4	1.25
S248439	20	08/02/2017 07:21 PM CDT	09/08/2017 06:26 AM CDT	52122783289	M	RT1	24	0.83
S248442	20	08/02/2017 07:24 PM CDT	09/08/2017 06:26 AM CDT	52122783289	M	RT1	24	0.83
S249076	3	08/03/2017 01:45 PM CDT	08/17/2017 03:45 PM CDT	46772663777	M	RT1	11	0.27
S252327	2	08/09/2017 10:39 AM CDT	08/17/2017 03:35 PM CDT	46772663777	M	RT1	7	0.29
S250109	1	08/07/2017 03:50 AM CDT	08/11/2017 09:35 AM CDT	46772665786	M	RT1	5	0.20
S250090	5	08/07/2017 03:11 AM CDT	08/23/2017 09:26 AM CDT	46772665786	M	RT1	13	0.38
S256783	8	08/17/2017 02:37 AM CDT	08/24/2017 12:00 AM CDT	52122783484	M	RT1	6	1.33
S248476	1	08/02/2017 11:00 PM CDT	08/03/2017 08:07 AM CDT	46772664970	M	RT1	2	0.50
S258258	1	08/21/2017 02:12 AM CDT	08/22/2017 08:02 AM CDT	46772664970	M	RT1	2	0.50
S248002	1	08/02/2017 08:23 AM CDT	08/02/2017 08:23 AM CDT	56827559751	E	RT1	1	1.00
S248143	1	08/02/2017 10:27 AM CDT	08/02/2017 10:41 AM CDT	56827559751	E	RT1	1	1.00
S248173	1	08/02/2017 11:07 AM CDT	08/02/2017 11:08 AM CDT	56827559751	E	RT1	1	1.00
S247663	1	08/02/2017 01:54 AM CDT	08/04/2017 07:06 AM CDT	47457680222	M	RT1	3	0.33
S263329	2	08/28/2017 09:02 PM CDT	09/07/2017 10:36 PM CDT	59835821829	C	RT1	9	0.22
S263331	2	08/28/2017 09:03 PM CDT	09/07/2017 09:46 PM CDT	59835821829	C	RT1	9	0.22
S254994	3	08/14/2017 11:00 AM CDT	08/24/2017 09:41 AM CDT	75188404876	M	RT1	9	0.33
S251437	2	08/08/2017 02:27 PM CDT	08/21/2017 05:10 PM CDT	49727339279	M	RT1	10	0.20
S248638	3	08/03/2017 03:40 AM CDT	08/23/2017 01:18 AM CDT	51762238005	M	RT1	13	0.23
S247466	3	08/01/2017 09:02 PM CDT	08/08/2017 02:43 PM CDT	55297967264	C	RT1	6	0.50
S248854	5	08/03/2017 10:56 AM CDT	08/10/2017 04:07 PM CDT	55297967264	C	RT1	6	0.83
S247467	3	08/01/2017 09:06 PM CDT	08/09/2017 04:09 PM CDT	55297967264	C	RT1	7	0.43
S247011	1	08/01/2017 08:56 AM CDT	08/04/2017 08:22 PM CDT	90187121996	M	RT1	4	0.25
S248301	1	08/02/2017 02:25 PM CDT	08/04/2017 08:22 PM CDT	90187121996	M	RT1	3	0.33
S249570	1	08/04/2017 07:22 AM CDT	08/10/2017 12:58 AM CDT	79632809568	C	RT1	4	0.25
S249488	1	08/04/2017 05:00 AM CDT	08/10/2017 01:23 AM CDT	75424369064	M	RT1	4	0.25
S253825	1	08/11/2017 12:37 AM CDT	08/11/2017 04:52 AM CDT	75424369064	M	RT1	1	1.00
S249488	1	08/04/2017 05:00 AM CDT	08/10/2017 01:23 AM CDT	75424369064	M	RT1	4	0.25
S249653	3	08/04/2017 09:20 AM CDT	08/04/2017 09:20 AM CDT	90187121996	M	RT1	1	3

Story ID	Plan Estimate	Creation Date	Accepted Date	Team ID	Sourcing Mix	Comm Treatment	Cycle Days	cycle Velocity (points per day)
5254787	1	08/14/2017 05:39 AM CDT	09/08/2017 06:05 AM CDT	46772665608	E	RT2	17	0.06
5254782	1	08/14/2017 05:37 AM CDT	08/18/2017 05:46 AM CDT	46772665608	E	RT2	4	0.25
5257483	1	08/18/2017 05:19 AM CDT	08/18/2017 05:19 AM CDT	46772665608	E	RT2	1	1.00
5257490	1	08/18/2017 05:24 AM CDT	08/18/2017 05:24 AM CDT	46772665608	E	RT2	1	1.00
5246779	2	08/01/2017 03:20 AM CDT	09/01/2017 01:55 AM CDT	76946621444	C	RT2	21	0.10
5265073	3	08/30/2017 05:01 AM CDT	09/29/2017 07:40 AM CDT	76946621444	C	RT2	23	0.13
5257456	6	08/18/2017 04:22 AM CDT	09/26/2017 01:26 AM CDT	76946621444	C	RT2	30	0.20
5246970	1	08/01/2017 08:17 AM CDT	08/04/2017 08:29 AM CDT	54780435424	E	RT2	4	0.25
5253966	1	08/11/2017 07:07 AM CDT	08/11/2017 07:07 AM CDT	54780435424	E	RT2	1	1.00
5252911	3	08/10/2017 07:09 AM CDT	08/10/2017 07:09 AM CDT	54780435424	E	RT2	1	3.00
5255526	2	08/15/2017 10:27 AM CDT	08/29/2017 10:14 AM CDT	51018646997	E	RT2	10	0.20
5256243	1	08/16/2017 08:27 AM CDT	08/21/2017 08:55 AM CDT	51018646997	E	RT2	4	0.25
5255517	1	08/15/2017 10:18 AM CDT	08/17/2017 02:26 PM CDT	51018646997	E	RT2	3	0.33
5255523	2	08/15/2017 10:24 AM CDT	08/17/2017 02:27 PM CDT	51018646997	E	RT2	3	0.67
5255001	3	08/14/2017 11:13 AM CDT	08/14/2017 11:13 AM CDT	51018646997	E	RT2	1	3.00
5254822	1	08/14/2017 07:53 AM CDT	09/07/2017 09:58 AM CDT	92951882300	M	RT2	17	0.06
5266269	1	08/31/2017 08:38 AM CDT	09/22/2017 04:13 AM CDT	92951882300	M	RT2	17	0.06
5261026	1	08/24/2017 06:38 AM CDT	08/24/2017 09:45 AM CDT	92951882300	M	RT2	1	1.00
5255356	1	08/15/2017 04:17 AM CDT	08/24/2017 07:36 AM CDT	58564499312	M	RT2	7	0.14
5248003	1	08/02/2017 08:23 AM CDT	08/08/2017 09:01 AM CDT	58564499312	M	RT2	5	0.20
5249785	3	08/04/2017 11:00 AM CDT	08/11/2017 10:48 AM CDT	58564499312	M	RT2	5	0.60
5251947	2	08/09/2017 04:36 AM CDT	08/09/2017 08:06 AM CDT	58564499312	M	RT2	1	2.00
5252956	1	08/10/2017 07:50 AM CDT	08/22/2017 08:17 AM CDT	59143878192	E	RT2	9	0.11
5252951	1	08/10/2017 07:48 AM CDT	08/16/2017 08:17 AM CDT	59143878192	E	RT2	5	0.20
5252950	1	08/10/2017 07:47 AM CDT	08/15/2017 08:20 AM CDT	59143878192	E	RT2	4	0.25
5252948	1	08/10/2017 07:46 AM CDT	08/14/2017 08:17 AM CDT	59143878192	E	RT2	3	0.33
5247920	1	08/02/2017 07:08 AM CDT	08/02/2017 08:17 AM CDT	59143878192	E	RT2	1	1.00
5248801	2	08/03/2017 09:35 AM CDT	08/11/2017 04:52 PM CDT	78363371808	M	RT2	6	0.33
5256716	1	08/16/2017 07:20 PM CDT	08/16/2017 07:27 PM CDT	78363371808	M	RT2	1	1.00
5256721	1	08/16/2017 07:22 PM CDT	08/16/2017 07:32 PM CDT	78363371808	M	RT2	1	1.00
5256717	2	08/16/2017 07:21 PM CDT	08/16/2017 07:27 PM CDT	78363371808	M	RT2	1	2.00
5256719	2	08/16/2017 07:21 PM CDT	08/16/2017 07:27 PM CDT	78363371808	M	RT2	1	2.00
5250906	3	08/08/2017 04:50 AM CDT	08/23/2017 03:35 AM CDT	55067617797	C	RT2	11	0.27
5250918	4	08/08/2017 05:02 AM CDT	08/23/2017 03:35 AM CDT	55067617797	C	RT2	11	0.36
5259092	1	08/22/2017 02:54 AM CDT	08/23/2017 03:35 AM CDT	55067617797	C	RT2	2	0.50
5250920	3	08/08/2017 05:02 AM CDT	08/08/2017 05:08 AM CDT	55067617797	C	RT2	1	3.00
5257164	1	08/17/2017 12:58 PM CDT	08/21/2017 09:13 AM CDT	55464498423	M	RT2	3	0.33
5247101	2	08/01/2017 10:19 AM CDT	08/08/2017 09:33 AM CDT	55464498423	M	RT2	5	0.40
5252530	5	08/09/2017 03:58 PM CDT	08/18/2017 03:22 PM CDT	55464498423	M	RT2	8	0.63
5248796	5	08/03/2017 09:27 AM CDT	08/11/2017 09:32 AM CDT	55464498423	M	RT2	6	0.83
5247779	1	08/02/2017 03:59 AM CDT	08/04/2017 03:57 AM CDT	71782753652	M	RT2	3	0.33
5246821	3	08/01/2017 05:08 AM CDT	08/14/2017 03:30 AM CDT	71782753652	M	RT2	9	0.33
5247778	1	08/02/2017 03:58 AM CDT	08/02/2017 03:58 AM CDT	71782753652	M	RT2	1	1.00
5256107	3	08/16/2017 05:25 AM CDT	08/16/2017 05:25 AM CDT	71782753652	M	RT2	1	3.00
5256109	3	08/16/2017 05:26 AM CDT	08/16/2017 05:26 AM CDT	71782753652	M	RT2	1	3.00
5246888	1	08/01/2017 07:25 AM CDT	08/03/2017 08:50 PM CDT	52866961080	M	RT2	3	0.33
5247146	2	08/01/2017 10:55 AM CDT	08/04/2017 07:08 PM CDT	52866961080	M	RT2	4	0.50
5246895	3	08/01/2017 07:30 AM CDT	08/03/2017 08:46 PM CDT	52866961080	M	RT2	3	1.00
5248711	2	08/03/2017 07:31 AM CDT	08/04/2017 07:12 PM CDT	52866961080	M	RT2	2	1.00
5246900	5	08/01/2017 07:32 AM CDT	08/03/2017 08:48 PM CDT	52866961080	M	RT2	3	1.67

Story ID	Plan Estimate	Creation Date	Accepted Date	Team ID	Sourcing Mix	Comm Treatment	Cycle Days	cycle Velocity (points per day)
5247678	5	08/02/2017 02:06 AM CDT	08/18/2017 12:12 PM CDT	47457676322	M	ACO	11	0.45
5247679	3	08/02/2017 02:07 AM CDT	09/19/2017 07:32 AM CDT	47457676322	M	ACO	31	0.10
5247472	8	08/01/2017 11:40 PM CDT	09/07/2017 10:36 AM CDT	52866336990	C	ACO	24	0.33
5247525	2	08/02/2017 12:33 AM CDT	09/08/2017 08:40 AM CDT	52866336990	C	ACO	25	0.08
5250262	2	08/07/2017 10:09 AM CDT	08/22/2017 02:25 PM CDT	46772666600	M	ACO	10	0.20
5250937	3	08/08/2017 05:18 AM CDT	08/22/2017 02:03 PM CDT	46772666600	M	ACO	10	0.30
5246862	1	08/01/2017 06:57 AM CDT	09/01/2017 12:25 PM CDT	90164028952	M	ACO	21	0.05
5246868	2	08/01/2017 07:04 AM CDT	10/10/2017 10:49 AM CDT	90164028952	M	ACO	47	0.04
5247342	6	08/01/2017 03:03 PM CDT	08/31/2017 09:58 AM CDT	55426342416	E	ACO	20	0.30
5247343	6	08/01/2017 03:03 PM CDT	10/02/2017 10:04 AM CDT	55426342416	E	ACO	41	0.15
5257839	1	08/18/2017 11:05 AM CDT	08/28/2017 08:38 AM CDT	56834008424	M	ACO	6	0.17
5257840	1	08/18/2017 11:08 AM CDT	08/28/2017 08:39 AM CDT	56834008424	M	ACO	6	0.17
5248044	3	08/02/2017 08:57 AM CDT	08/04/2017 03:29 PM CDT	55426154266	M	ACO	3	1.00
5246787	3	08/01/2017 03:44 AM CDT	09/08/2017 02:09 PM CDT	60662807485	M	ACO	25	0.12
5248178	5	08/02/2017 11:14 AM CDT	08/21/2017 12:00 PM CDT	60662807485	M	ACO	12	0.42
5248685	8	08/03/2017 06:15 AM CDT	08/16/2017 01:51 AM CDT	57216353139	M	ACO	9	0.89
5246777	2	08/01/2017 03:09 AM CDT	08/21/2017 01:11 AM CDT	54285666660	M	ACO	13	0.15
5247083	5	08/01/2017 09:59 AM CDT	09/12/2017 07:24 AM CDT	55405721183	M	ACO	27	0.19
5248348	3	08/02/2017 02:58 PM CDT	08/07/2017 09:35 AM CDT	88119056440	E	ACO	4	0.75
5248963	1	08/03/2017 12:36 PM CDT	08/07/2017 09:35 AM CDT	88119056440	E	ACO	3	0.33
5247429	2	08/01/2017 04:58 PM CDT	09/24/2017 11:13 PM CDT	91967422940	E	ACO	35	0.06
5247430	3	08/01/2017 05:00 PM CDT	08/22/2017 12:25 PM CDT	91967422940	E	ACO	14	0.21
5247324	2	08/01/2017 02:47 PM CDT	09/03/2017 03:03 PM CDT	78422039228	M	ACO	21	0.10
5246810	5	08/01/2017 04:42 AM CDT	08/17/2017 10:39 AM CDT	48214864375	M	ACO	11	0.45
5247200	1	08/01/2017 11:51 AM CDT	09/20/2017 01:48 PM CDT	57141133137	M	ACO	33	0.03
5247662	2	08/02/2017 01:51 AM CDT	08/10/2017 04:17 PM CDT	57141133137	M	ACO	6	0.33
5246801	2	08/01/2017 04:27 AM CDT	08/22/2017 09:21 AM CDT	89980193308	E	ACO	14	0.14
5247110	1	08/01/2017 10:30 AM CDT	08/23/2017 01:25 PM CDT	55574870092	M	ACO	15	0.07
5247112	1	08/01/2017 10:31 AM CDT	08/02/2017 09:15 AM CDT	55574870092	M	ACO	2	0.50
5247115	2	08/01/2017 10:35 AM CDT	08/04/2017 08:20 AM CDT	55238929294	M	ACO	4	0.50
5247160	1	08/01/2017 11:06 AM CDT	08/14/2017 11:50 AM CDT	55238929294	M	ACO	9	0.11
5247992	5	08/02/2017 07:58 AM CDT	09/05/2017 07:25 AM CDT	78493315800	M	ACO	21	0.24
5247993	5	08/02/2017 08:00 AM CDT	09/05/2017 07:12 AM CDT	78493315800	M	ACO	21	0.24
5248132	5	08/02/2017 10:03 AM CDT	08/16/2017 11:05 AM CDT	57440300698	M	ACO	10	0.50
5246954	1	08/01/2017 08:06 AM CDT	08/04/2017 09:08 AM CDT	96659135880	M	ACO	4	0.25
5246741	1	08/01/2017 02:22 AM CDT	08/01/2017 09:02 AM CDT	57222660301	M	ACO	1	1.00
5246749	1	08/01/2017 02:43 AM CDT	08/01/2017 09:03 AM CDT	57222660301	M	ACO	1	1.00
5247415	1	08/01/2017 04:06 PM CDT	08/25/2017 10:46 AM CDT	53919352305	M	ACO	16	0.06
5247369	1	08/01/2017 03:24 PM CDT	08/23/2017 04:38 PM CDT	51755851126	M	ACO	15	0.07
5247459	2	08/01/2017 07:27 PM CDT	08/07/2017 10:02 AM CDT	51755851126	M	ACO	4	0.50
5247287	3	08/01/2017 01:39 PM CDT	09/29/2017 12:21 PM CDT	90951454264	M	ACO	40	0.08
5259352	1	08/22/2017 08:59 AM CDT	09/18/2017 09:10 AM CDT	90951454264	M	ACO	18	0.06
5247336	2	08/01/2017 02:59 PM CDT	08/22/2017 07:06 AM CDT	57222660714	M	ACO	14	0.14
5247894	2	08/02/2017 06:49 AM CDT	08/22/2017 12:09 PM CDT	57222660714	M	ACO	13	0.15
5247338	5	08/01/2017 03:01 PM CDT	10/05/2017 10:43 AM CDT	55426154702	M	ACO	44	0.11
5247340	5	08/01/2017 03:02 PM CDT	10/02/2017 10:00 AM CDT	55426154702	M	ACO	41	0.12
5247296	2	08/01/2017 01:54 PM CDT	10/04/2017 01:44 PM CDT	53431716723	M	ACO	43	0.05
5247372	1	08/01/2017 03:27 PM CDT	08/01/2017 03:27 PM CDT	1.03956E+11	M	ACO	1	1.00
5246793	1	08/01/2017 04:09 AM CDT	08/01/2017 04:09 AM CDT	57711572553	C	ACO	1	1.00
5246818	1	08/01/2017 05:01 AM CDT	08/01/2017 05:01 AM CDT	57711572553	C	ACO	1	1.00