Effects of Geographic and Demographic Dispersion on the Performance of Systems Engineering Teams

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Dedication

This work is dedicated to my wife Karina, who has been the most important person in my life and taught me that balance and love are key components for happiness. Every step and every triumph in my life has been achieved with her support.

This work is also dedicated to my parents, Alicia and José who have been my mentors, my source of energy and an example for me about dedication, constancy and sacrifice.

Finally, I also dedicate this dissertation to my brother Pablo, my nephew Alejandro and all family members and friends whose support have encouraged me during the past years in the pursuit of this degree.

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Abstract of Dissertation

Effects of Geographic and Demographic Dispersion on the Performance of Systems Engineering Teams

Globalization and the increasing complexity of systems require collaboration across multidisciplinary teams. Systems Engineering (SE) teams are often geographically and demographically dispersed; such dispersion might affect the ability of the teams to produce their desired outcomes.

The main objective of this research study was to determine how geographic and demographic dispersion affect the performance of a SE team along each phase of the SE life cycle, and which dispersion factors have more influence on the performance of an SE team for each life cycle phase.

This research study started with an exhaustive review of the literature related to team dispersion and team performance. The next step was building a conceptual model grounded in theory, which allowed the measurement of geographic and demographic dispersion through the use of well-established indices recognized by the scientific community. The data collection process successfully gathered information about projects geographically distributed throughout 57 cities in 38 countries.

Finally, multiple linear regression analysis (MLR) was conducted for each SE life cycle phase, to predict team performance (dependent variable) based on geographic and demographic variables (independent variables). The results of MLR show that independent variables statistically significantly predicted team performance along each phase of the SE life cycle, except for the Retirement phase, which was excluded from the

model due to low amount of data collected about team performance for this phase (only 26.66% of the identified projects reached the Retirement phase at the time of data collection).

Considering the MLR results, this research study identified the geographic and demographic dispersion factors for each SE Life Cycle phase that are high predictors of team performance. Additionally, Age and Primary Language were identified as the demographic dispersion factors that added statistically significantly to the prediction of team performance during all phases of the SE Life Cycle.

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List of Acronyms/Symbols

ANOVA - Analysis of Variance

ICT – Information and Communication Technologies

KD – Knowledge Diversity

MLR - Multiple Linear Regression

SCD – Social Category Diversity

SDI – Space and Distance Index

SE – Systems Engineering

TZI – Time Zone Index

VD – Value Diversity

Glossary of Terms

Concept Phase: "Is executed to assess new business opportunities and to develop preliminary system requirements and a feasible design solution" (Incose Systems Engineering Handbook: Version 3.1, 2007).

Development Phase: "Is executed to develop a system-of-interest that meets acquirer requirements and can be produced, tested [verified], evaluated, operated, supported, and retired" (Incose Systems Engineering Handbook: Version 3.1, 2007).

Extra-role Performance Behaviors: behaviors not listed formally as job requirements but that help the team as a social system (Ganesh & Meenakshi, 2010).

Faultlines: "hypothetical dividing lines that may split a group into subgroups based on one or more attributes" (Lau & Murnighan, 1998).

Geographic Dispersion: "increasing with greater levels of physical separation among team members (i.e., different rooms, hallways, floors, buildings, cities, countries)" (Cummings & Haas, 2012).

Demographic Dispersion: "The definition of demography is traditionally conceptualized in terms of visible differences in age, gender, and race. Individuals may also differ on less visible characteristics such as level of education, tenure with the company or functional background" (Ting-Peng, Chih-Chung, Tse-Min, & Binshan, 2007).

Discontinuities: changes in existing work conditions for the team, including geography, time zone, and organizational and national culture (Chudoba, Wynn, Lu, & Watson-Manheim, 2005).

Dispersed Teams: "groups of people with a common purpose who carry out interdependent tasks across locations and time, using technology to communicate" (Assudani, 2011).

High Performance Team: "small group of people with complementary skills who have a common goal and working approach, who hold themselves mutually accountable, and who are genuinely concerned for not only the success of the team but the personal growth and goals of each other" (Componation, Youngblood, Utley, & Farrington, 2008).

Homoscedasticity: It is the assumption that all error terms (e_i) have the same variance (σ^2). When the assumption is violated we have what is called heteroscedasticity (Lattin, 2003).

Multicollinearity: Occurs when two or more independent variables are highly correlated with each other, which cause difficulties when determining the contribution of a single variable to the variance explained ("Laerd Statistics," 2013).

Multiple Linear Regression: "Multiple linear regression is used to analyze the relationship between a set of independent variables and a single dependent variable, allowing researchers to determine the type of relationship between the variables, the statistical significance of the relationship, and also how well the model generalize to observations outside the sample" (Lattin, 2003).

Production Phase: "Is executed to produce or manufacture the product, to test [verify] the product, and to produce related supporting and enabling systems as needed" (Incose Systems Engineering Handbook: Version 3.1, 2007).

Relationship Conflict: "interpersonal incompatibilities among team members, such as tension, animosity, and annoyance among members" (Ting-Peng et al., 2007).

Retirement Phase: "Is executed to provide for a removal of a system-of-interest and related operational and support services, and to operate and support the retirement system itself" (Incose Systems Engineering Handbook: Version 3.1, 2007).

Systems Engineering: "Is an iterative process of top-down synthesis, development and operation of a real-world system that satisfies, in a near optimal manner, the full range of requirements for the system" (Incose Systems Engineering Handbook: Version 3.1, 2007).

Systems Engineering Life Cycle: “Framework for meeting the stakeholders’ needs in an orderly and efficient manner. This is usually done by defining life cycle stages, and using decision gates to determine readiness to move from one stage to the next” (Incose Systems Engineering Handbook: Version 3.1, 2007).

Support Phase: “Is executed to provide logistics, maintenance, and support services that enable continued system-of-interest operation and a sustainable service” (Incose Systems Engineering Handbook: Version 3.1, 2007).

Task Conflict: “conflict as the disagreement among team members regarding the content of the tasks being performed and differences in viewpoints, ideas, and opinions” (Ting-Peng et al., 2007).

Team Performance: “the process and product success, evidenced by its on-time completion within-budget and meeting system requirements” (Espinosa, Cummings, & Pickering, 2012).

Transactive Memory: “Transactive memory systems are multimember cognitive systems in which groups of individuals efficiently organize, store, retrieve, and share information” (O’Leary & Mortensen, 2010).

Utilization Phase: “Is executed to operate the product, to deliver services within intended environments and to ensure continued operational effectiveness” (Incose Systems Engineering Handbook: Version 3.1, 2007).

Chapter 1 - Introduction

Geographic and demographic dispersion has been a subject that captured the attention of several researchers during the last years. Different authors have contributed to the state of the art and proposed a set of definitions for dispersed and virtual teams.

Hacker and Lang (2000) defined "virtual teams" as "self-managed knowledge work teams with distributed expertise that are fluid in terms of membership, leadership, and boundaries" (Hacker & Lang, 2000).

According to Massey et al. (2003), a "global virtual team" is composed by "a group of geographically dispersed individuals who are assembled via technology to accomplish an organizational task" (Massey, Montoya-Weiss, & Yu-Ting, 2003).

Martins et al. (2004) defined "virtual teams" as "teams whose members use technology to varying degrees in working across locational, temporal, and relational boundaries to accomplish an interdependent task" (Martins, Gilson, & Maynard, 2004).

Another definition was provided by Kirkman and Mathieu (2005), were they consider "virtual teams" as "groups of geographically and/or organizationally dispersed coworkers that are assembled using a combination of telecommunications and information technologies to accomplish a variety of critical tasks" (Kirkman & Mathieu, 2005).

Finally, "Dispersed teams" are defined by Assudani (2011) as "groups of people with a common purpose who carry out interdependent tasks across locations and time, using technology to communicate" (Assudani, 2011).

Several similarities and differences between virtual and local teams have been identified in previous research (Hacker & Lang, 2000):

- Virtual and local teams use clearly established and measurable objectives in order to increase cohesion and task alignment.
- Virtual and local teams use clearly defined procedures for team interaction, conflict resolution and decision making.
- Virtual team members must replace face-to-face interactions with technology supported communications.
- Virtual team members must balance priorities and loyalties between the local sub team and the virtual team.
- Both, virtual and local teams must overcome cultural differences, often stronger in dispersed teams.

The main benefit of a dispersed team is the availability of diverse knowledge and expertise (Assudani, 2011). Additionally, a dispersed team is often characterized as being culturally diverse and geographically dispersed, with team members usually participating in several projects with competing priorities (Daim et al., 2012). Dispersed engineering teams often undertake complex, non-routine projects with uncertain outcomes (Cummings & Haas, 2012).

Researchers have indicated that dispersed teams work on complex, interdependent tasks using technology to overcome three types of boundaries: spatial, temporal, and relational. The spatial boundary is related to physical dispersions of team members, the temporal boundary refers to members located in different time zones and the synchronicity of the performed work, and the relational boundary is associated with differences in networks such as departments, organizations, and cultural sub-groups (Martins et al., 2004). In an attempt to explain the nature and implications of team dispersion, other researchers have used the concept of “discontinuities”, which is defined as changes in existing work conditions for the team, including geography, time zone, and organizational and national culture (Chudoba et al., 2005).

Several factors have been identified as enablers of the use of dispersed collaboration. Fast changing global environments and increasingly cost-effective communication technologies have increased the use of dispersed teams during the innovation process (Bertels, Kleinschmidt, & Koen, 2011; Cummings & Haas, 2012).

The use of dispersed teams has led to a new type of problems for team leaders and project managers, especially in order to effectively maintain an appropriate level of communication among team members. When leading a team dispersed across different locations, a team leader needs to coordinate effectively and synchronize the execution of tasks and activities, ensure the efficient and effective sharing of information and knowledge, and the effective communication among team members (Daim et al., 2012).

Working with distributed teams has documented advantages, as noted in previous research. The competitiveness and flexibility of the organization may be improved because the best individuals for a given position are hired based on appropriate skills, regardless of their physical location (Martins et al., 2004). According to O’Leary and Mortensen (2010), additional benefits of dispersed teams include: access to distributed expertise, expansion of market research, employee flexibility, and reduction of real estate costs (O’Leary & Mortensen, 2010). Furthermore, globally dispersed teams provide access to lower-cost human capital and flexibility in work arrangements (Zhang, Tremaine, Milewski, Fjermestad, & O'Sullivan, 2012).

In the other hand, researchers have identified disadvantages related to the use of dispersed engineering teams, for instance de-contextualization which makes difficult the creation and sharing of tacit knowledge among team members even with the use of appropriate technology collaboration tools (Bertels et al., 2011).

There have been many studies conducted on the field of team dispersion, including analyses of the geographic and demographic dispersion effects on team performance (Agrawal, 2012; Ahuja, 2010; Espinosa et al., 2012; Haas, 2010; Higgs, Plewnia, & Ploch, 2005; Jehn & Bezrukova, 2004; Jehn & Mannix, 2001; Jehn, Northcraft, & Neale, 1999; Jill & Kepa, 2003; Lattimer, 1998; Mannix & Neale, 2005; Martins et al., 2004; Massey et al., 2003; O'Leary & Cummings, 2007; O’Leary & Mortensen, 2010; Russo, 2012; Saji, 2004; Sakuda, 2012; Ting-Peng et al., 2007; Vodosek, 2007). However, previous studies focused on project teams in general. This study specifically focuses on SE teams, which have inner characteristics that differ from traditional teams, and whose work is conducted according to a clearly defined SE life cycle.

The main gap noted in the literature is that previous researchers have considered team performance only as the sole measure of cost and schedule at the end of the engineering project. Consequently, there are no studies of the effects of geographic and demographic dispersion on the performance of SE teams relative to each phase of the SE life cycle. This study has measured the effects of dispersion among the different phases of the ISO/IEC 15288 SE life cycle: concept, development, production, utilization, support and retirement (Incose Systems Engineering Handbook: Version 3.1, 2007).

Team managers use systems engineering as an approach to find a better balance of cost, schedule, and performance. However, they often lack clear guidance on techniques and practices designed to effectively tailor SE teams (Componation et al., 2008).

To address the aforementioned deficiencies and to contribute to the state of the art of SE, this study has examined the effects of geographic and demographic dispersion on the performance of SE teams. Therefore, the significance of this study lies in the following considerations:

- Organizations increasingly have employed geographically dispersed teams to perform their core work activities (Polzer, Crisp, Jarvenpaa, & Kim, 2006).
- The study of demographic dispersion is critical for systems engineers and global team managers because team members are not only facing physical separations, but also cultural differences (Muethel & Hoegl, 2010).
- Previous research has identified team performance measurement as an essential component of team success, enabling the identification of performance issues and improvement actions. Additionally, several studies have been conducted to examine the effects of dispersion on performance outcomes, exploring different dimensions of dispersion such as space, time, and demographic characteristics (Agrawal, 2012; Alexander, Nuchols, Bloom, & Lee, 1995; Haas, 2010; Jehn & Bezrukova, 2004; Jehn & Mannix, 2001; Jill & Kepa, 2003; Lattimer, 1998; Mannix & Neale, 2005;

Martins et al., 2004; O'Leary & Mortensen, 2010; Russo, 2012; Saji, 2004; Sakuda, 2012; Vodosek, 2007).

- Previous studies addressing this problem have only taken into consideration geographic dispersion or demographic dispersion separately, measuring one or the other's effects on team performance.
- Previous studies about the effects of dispersion on team performance have not taken into consideration the different phases of the Systems Engineering life cycle.
- This is the first study to combine all variables together, geographic and demographic dispersion and the performance of an engineering team along each phase of the Systems Engineering life cycle.

The following questions have been addressed in this paper:

Research Question 1: How is the performance of an engineering team affected by geographic and demographic dispersion along each phase of the SE life cycle?

Research Question 2: Which geographic and demographic dispersion factors have more influence on the performance of an engineering team along each one of the SE life cycle phases?

As covered in Chapter 2- Theory and Hypothesis Development*Chapter 2*, this research study started with an exhaustive review of the literature related to team dispersion and team performance. The next step was building a conceptual model grounded in theory that allowed the measurement of geographic and demographic dispersion through the use of well-established indices recognized by the scientific community.

Chapter 3 - Variables Measurement and Data Collection, covers the measurement of geographic and demographic dispersion variables, as well as the data collection process that successfully gathered information about projects geographically distributed throughout 57 cities in 38 countries.

Chapter 4 - Data Analysis and Results, covers the implementation of multiple linear regression analysis (MLR) for each SE life cycle phase, to predict team performance (dependent variable) based on geographic and demographic variables (independent variables). The results of MLR show that independent variables statistically significantly predicted team performance along each phase of the SE life cycle, except for the Retirement phase, which was excluded from the model due to low amount of data collected about team performance for this phase (only 26.66% of the identified projects reached the Retirement phase at the time of data collection).

Finally, Chapter 5 - Conclusions, Limitations, and Recommendations, summarizes the conclusions for this study, its limitations, and also recommends several areas for further research opportunities.

Chapter 2 - Theory and Hypothesis Development

Dispersed collaboration has been identified as an important element for the success of systems engineering teams. Business globalization and the use of cost-effective communication tools have increased the utilization of dispersed collaboration in engineering teams assembled in order to undertake large-scale and heterogeneous problems. In this scenario, engineering teams take advantage of the availability of qualified personnel, with the appropriate knowledge and skills, who can collaborate despite geographical constraints (Bertels et al., 2011; DeFranco, Neill, & Clariana, 2011).

Research on the effects of geographic and demographic dispersion on the performance of SE teams requires examination of three key areas: geographic dispersion, demographic dispersion, and team performance.

It is important to study each area for the following reasons:

(a) Organizations increasingly have employed geographically dispersed teams to perform their core work activities (Polzer et al., 2006).

(b) The study of demographic dispersion is critical for systems engineers and global team managers because team members are not only facing physical separations, but also cultural differences (Muethel & Hoegl, 2010).

(c) Previous research has identified team performance measurement as an essential component of team success, enabling the identification of performance issues and improvement actions. Additionally, several studies have been conducted that examine the effects of dispersion on performance outcomes, exploring different dimensions of dispersion such as space, time, and demographic characteristics (Agrawal, 2012; Alexander et al., 1995; Haas, 2010; Jehn & Bezrukova, 2004; Jehn & Mannix, 2001; Jill & Kepa, 2003; Lattimer, 1998; Mannix & Neale, 2005; Martins et al., 2004; O'Leary & Mortensen, 2010; Russo, 2012; Saji, 2004; Sakuda, 2012; Vodosek, 2007).

2.1. Geographic Dispersion

Research indicates that daily contact among team members is significantly reduced when they work more than 30 meters apart from each other (Kirkman & Mathieu, 2005). Cummings and Haas (2012) noted that geographic dispersion is "increasing with greater levels of physical separation among team members (i.e., different rooms, hallways, floors, buildings, cities, countries)" (Cummings & Haas, 2012).

O'Leary and Cummings (2007) conceptualized geographic dispersion as a continuous construct with three critical dimensions: *spatial, temporal and configurational* (O'Leary & Cummings, 2007).

Spatial Separation

Spatial separation is a key criterion to measure team "virtualness", and can range from teams with all members located at the same place to teams where each team member is located in a different country (Ganesh & Meenakshi, 2010). Different factors have been identified as enablers of spatial separation as the need of decreasing organizational real estate costs and the need of decreasing costs and commuting time for employees. Also, spatial dispersion has been related with outcomes like reductions in spontaneous communications between team members because face-to-face interaction is less likely to happen (O'Leary & Cummings, 2007).

There are identified benefits for co-located teams which relationships among team members often take advantage of face-to-face communication, familiarity between members because of physical closeness, and positive biases created between people who categorize each other as in-group members (Polzer et al., 2006).

The first level of spatial dispersion between team members is across buildings where there are fewer opportunities for informal interactions and spontaneous communication and it is more difficult to schedule in-person meetings. In this scenario, communication between team members is based on technology tools like email, chat and phone, which may cause interpretation issues and are less rich that face-to-face communication (Cummings & Haas, 2012).

A second level of spatial dispersion between team members is when they are located in different cities facing coordination and communication difficulties caused by dispersion, and also facing new demands of attention from local colleagues who ask team members to focus on other tasks different than the ones assigned in the focal team (Cummings & Haas, 2012).

Finally, a third level of spatial dispersion is when team members are located in different countries; in this scenario they face not only difficulties originated on physical distance and often temporal differences, but also potential adversities generated by cultural differences (Cummings & Haas, 2012).

Temporal Separation

According to Ganesh and Meenakshi (2010), temporal separation is highly related with spatial separation, and is caused by differences in time zones among the places in which members work. Additionally, temporal separation can lead to asynchronous interaction between team members, which is a limitation teams members usually overcome by matching a percentage of their working hours with the working hours of other members and clients among geographic locations (Ganesh & Meenakshi, 2010).

As an outcome of temporal dispersion, the team reduces its ability to solve real-time problems because of the decrease on potential synchronous interaction. One of the factors identified as enabler of temporal separation is the adoption of work approaches designed to provide customer support on global organizational environments (O'Leary & Cummings, 2007).

Some researchers have concluded that the effects of temporal separation on teamwork are stronger that the ones caused by spatial separation and often consider time separation as a consequence of spatial separation. That is the reason why Espinosa et al. (2012) indicated that temporal separation cannot occur without the presence of some form of spatial separation, indicating that spatial and temporal separation should be studied together because they are often associated with each other (Espinosa et al., 2012).

Previous research has indicated that spatial and temporal separation usually correlates statistically, except for teams dispersed in a North–South geographic configuration. There are key aspects of spatial separation identified in teams without temporal separation:

1) Communication technologies restore some of the benefits of on-site collaboration eliminated by the use of spatial separation;

2) Team members are free to select a communication mode, either synchronous or asynchronous, depending on what they consider more adequate at the moment and taking advantage of the fact that working hours fully overlap for all of them; and

3) Team performance is not affected by the magnitude of the distance between team members. On the contrary, with temporal separation all those aspects are important for team performance especially when the time zone difference between subgroups is large; in that scenario team coordination becomes difficult when team members need to contact other colleagues and coordinate meetings and tasks (Espinosa et al., 2012).

Configurational Separation

To achieve a successful team configuration, team leaders and project managers must select members with previous experience working together, in order to reduce negative effects caused by virtualness (Ganesh & Meenakshi, 2010).

Configurational separation is related with isolation and imbalance factors. Isolation in a team has an impact on how team members are aware of fellow team members, and usually the presence of isolated team members is the result of the need to hire specialized expertise independently of the geographic location. Imbalance between subgroups increases conflict and affects decision-making because of majority influence (O'Leary & Cummings, 2007).

According to O’Leary and Mortensen (2010), dispersed teams with isolated team members present special characteristics which differentiate them from dispersed teams with subgroups. Isolates do not trigger the same categorization-driven effects as teams with minorities because they do not experience face-to-face and unplanned interactions with local team members that are likely to increase individual identification and in-group/out-group differentiation. The authors indicated also the existence of qualitative differences between the experience of a subgroup, even a small one, and the experience of a team member geographically isolated. Also, the authors found that dispersed teams with isolated team members avoid negative effects experienced by teams with subgroups, even experiencing positive outcomes for the isolated members and the collocated subgroups (O'Leary & Mortensen, 2010).

Previous research also provided insights on the role and impact of isolated team members in geographically dispersed teams. O'Leary and Mortensen (2010) found that members in isolation face "special pressures, stronger majority/minority boundaries, entrapment in stereotypical roles, and general social isolation". Isolated members in this study faced fewer negative effects than non-isolated team members, and according to data collected about contribution, influence and communication, they were not socially isolated. Finally, the authors found that teams with isolated team members had better dynamic than collocated teams, where isolates serves unique and beneficial roles for the whole team (O'Leary & Mortensen, 2010).

O'Leary and Mortensen (2010) also proposed that imbalance between geographic subgroups is the cause of many negative effects in the performance of a dispersed team, such as communication issues, reduced trust, and increased conflict. The authors concluded that imbalanced subgroups have significant effects on the dynamics of a geographically dispersed team and should be accounted for in practice. (O'Leary & Mortensen, 2010).

Geographic Dispersion and Virtuality

Technology collaboration tools are critical in the daily work of dispersed teams, allowing team members to communicate, create, and share knowledge and overcome the negative effects of dispersion. Both concepts (geographic dispersion and technology-based communication) are analyzed under the topic of "virtuality" (Ganesh & Meenakshi, 2010).

Previous research has been conducted to analyze the relationship between geographic dispersion and virtuality. According to Kirkman (2005), there is no direct relationship between geographic dispersion and virtuality; a team might conduct its interactions using asynchronous virtual tools while its members may all be located in the same site. Also, a team with high geographic dispersion might be low in virtuality (Kirkman & Mathieu, 2005).

Considering that team members from both dispersed and collocated teams can communicate and coordinate tasks in an asynchronous way with high virtuality, Kirkman and Mathieu (2005) defined team virtuality with three dimensions graphically represented in ***Error! Reference source not found.*** and described below:

(a) The extent to which the team uses virtual collaboration tools to coordinate and execute tasks. In this context, virtuality can be measured for every team considering how much the team relies on virtual tools to communicate and collaborate instead of face-to-face interaction, the more the team reliance on virtual tools the higher the index of virtuality for that team (Kirkman & Mathieu, 2005).

(b) The level of informational value provided by virtual tools. Informational value, acknowledges that virtual tools are used for other activities than communication between team members, for example the exchange of data useful for team effectiveness. In this case there is an inverse relationship between the informational value of the virtual tools and the level of virtuality of the team (Kirkman & Mathieu, 2005).

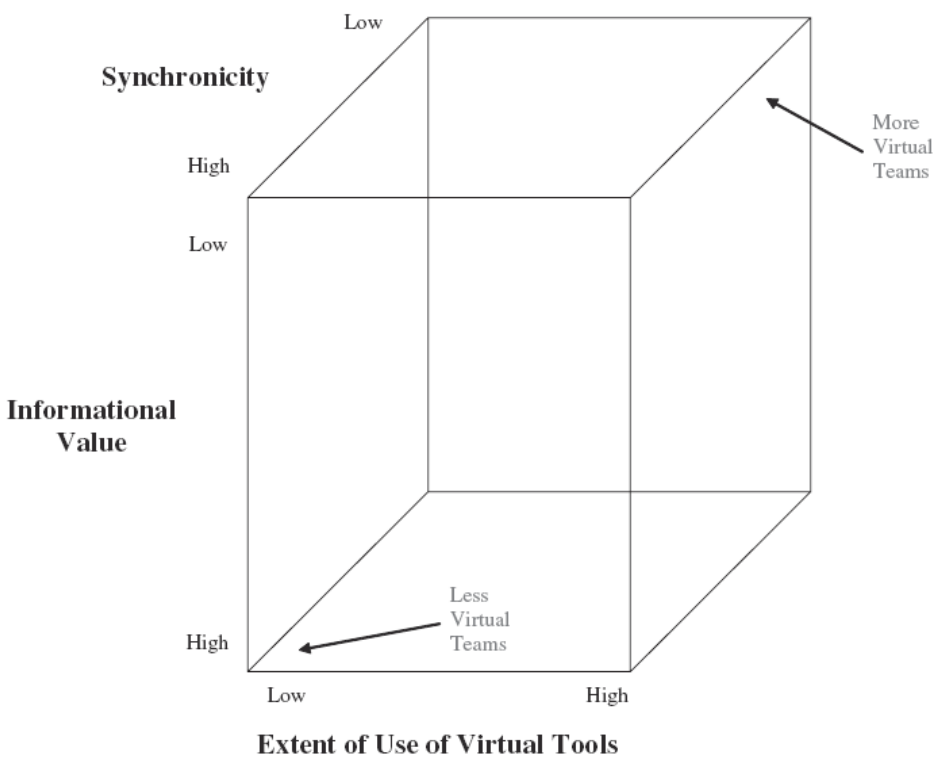

Figure 1 ***-*** *Three-Dimensional Model of Team Virtuality*

Source: *Kirkman and Mathieu (2005)*

(c) The level of synchronicity of the interaction between team members. Synchronous communication between team members is real time, while asynchronous communication is associated with a time lag. The level of virtuality for a team is increased as more asynchronous communications are conducted between members (Kirkman & Mathieu, 2005).

In a subsequent study, Ganesh (2010) found that virtuality negatively influenced "extra-role performance behaviors" in a team, which are behaviors not listed formally as job requirements but that help the team as a social system (Ganesh & Meenakshi, 2010).

2.2. Demographic Dispersion

Researchers have identified three types of demographic diversity: Knowledge Diversity (KD), Social Category Diversity (SCD) and Value Diversity (VD) (Ting-Peng et al., 2007).

Knowledge Diversity

KD (otherwise known as informational diversity) is related to the differences in knowledge base and experience amongst team members. When team members experience dispersion in aspects like work experience, training preparation and educational background it increases the chances of conflict caused by differences in opinions (Ting-Peng et al., 2007).

In addition, prior research has indicated that distributed teams whose members have differences in educational backgrounds have experienced more difficulties when defining the directions to proceed in a specific situation, compared to dispersed teams with members with similar educational backgrounds. One output of the differences in educational background is the increase in the number of conflicts the team experience with task-related issues (Ting-Peng et al., 2007).

Social Category Diversity

Usually when people talk about diversity they refer to Social category diversity (SCD) which refers to explicit differences among team members in aspects related to social category membership like race, gender, age, nationality and primary language (Jehn et al., 1999).

When members of a distributed team belong to different social categories, often relationship and interpersonal conflict arise such as hostility among members because of personal disagreements and preferences on issues not related directly to project issues (Ting-Peng et al., 2007).

The literature shows a large number of studies conducted on social category diversity (SCD). Cultural differences have particularly been identified as a critical challenge for team leaders of globally dispersed teams (Muethel & Hoegl, 2010). According to O'Leary and Mortensen (2010), socio-demographic differences are often correlated with spatial and temporal dispersion (O'Leary & Mortensen, 2010).

Kirkman and Mathieu (2005) defined "culture" as a "set of values shared by a group of people, frequently used to distinguish one group from another" (Kirkman &

Mathieu, 2005). In this scenario, team members use cultural values as guidance for the perception of the surrounding environment, which leads important behavioral aspects as decision-making and social interaction. Primary language is one of the most relevant factors of SCD related with performance in a dispersed team because most of the communication is mediated through ICT. Cross-cultural differences often act together with other types of dispersion like spatial and temporal separation (Chudoba et al., 2005).

According to Muethel and Hoegl (2010), SCD increase tension on the team affecting team integration and cohesion. It is reflected when, as dispersion increases, team leaders lose their ability to effectively influence and supervise the work of other team members. This is caused because there are fewer opportunities to exert an effective leadership, restricted by cultural differences (Muethel & Hoegl, 2010).

Language differences have been identified by researchers as one of the main barriers to communication in a project; which are: (1) language differences among team members and clients, (2) perception difference about project issues, and (3) lack of a clearly defined communication plan. Team leaders and project managers in dispersed teams must control these aspects in order to achieve the successful completion of the project (Daim et al., 2012).

Daim et al. (2012) also identified the most common problems usually faced by a dispersed team, most of them related with SCD factors: (a) Poor balance between work and life time because of a large number of meetings, (b) Limited continuity of effort between real-time meetings, (c) Limited assimilation of information and poor decision making due to constraints related to meeting time, (d) Multi-Cultural constraints with teams where usually English speaking members are the majority, (e) Limited logs of agreements, (f) Low exploitation of the workday because of temporal separation, (g) Poor utilization of collaborative applications (Daim et al., 2012).

In order to overcome social category diversity issues, previous research has identified actions to be executed by team leaders and global managers, such as diversity awareness training and the implementation of face-to-face meetings to promote teambuilding at the initial phases of the project (Hacker & Lang, 2000).

Value Diversity

Value Diversity is associated with member's differences in terms of what they think about the tasks, goals, targets, or missions (Ting-Peng et al., 2007).

Woehr, Arciniega and Poling (2013) conducted a study to explore the potential impact of VD in team processes and task performance. The results of this study indicated that VD had no significant impact on task performance; however, diversity associated with several value dimensions had a significant unique effect on team process (Woehr, Arciniega, & Poling, 2013).

Even though VD is a recognized index in the literature, we are not including it into the analysis for this study as its measurement is complex and based primarily on team members' perceptions.

Demographic Diversity and Faultlines

Knowledge Diversity and Social Category Diversity take into account several dispersion variables (e.g. major, education level, experience, age, nationality, gender, etc.), which in previous research have been measured individually using dispersion indexes when analyzing their effect on work group outcomes (Haas, 2010; Jehn & Bezrukova, 2004; Jehn et al., 1999; Ting-Peng et al., 2007; Vodosek, 2007).

Previous researchers noted that, when analyzing the relationship between demographic dispersion and team performance, the inconsistent results obtained in the past were caused because most of the studies focused on a single characteristic of dispersion at a time, without considering simultaneously the concurrent effects caused by several dimensions of diversity (Lau & Murnighan, 1998; Thatcher, Jehn, & Zanutto, 2003; Zanutto, Bezrukova, & Jehn, 2011).

In that scenario, Lau and Murnighan (1998) introduced the concept of "faultlines," defined as "hypothetical dividing lines that may split a group into subgroups based on one or more attributes" (Lau & Murnighan, 1998). The strength of the faultlines depends on how aligned are the different demographic attributes for a specific team. Therefore, the main difference between demographic faultlines and diversity indexes is related to the fact that faultlines take into consideration the alignment of several diversity attributes while diversity indexes are designed to measure each attribute separately (Thatcher & Patel, 2011).

According to Lau and Murnighan (1998), the effects of demographic diversity and faultlines are different. Demographic diversity is related to increases in task and interpersonal conflict and creativity, while faultlines are related also to intra-group conflict with less impact on creativity (Lau & Murnighan, 1998).

Considerable research has been conducted on the relationship between demographic faultlines and their effect on team performance, including the definition of faultline measures (Gratton, Voigt, & Erickson, 2007; Lau & Murnighan, 1998; Maloney

& Zellmer-Bruhn, 2006; Molleman, 2005; Shaw, 2004; Thatcher et al., 2003; Thatcher & Patel, 2011; Trezzini, 2008; Zanutto et al., 2011).

In a study conducted with 45 teams, Polzer et al. (2006) extended the concept of faultlines also to geographic dispersion and proposed that geographic dispersion factors activate faultlines and negatively affects the performance of a team. The results of the study show that geographic faultlines increase conflict and reduce trust in a team (Polzer et al., 2006).

Gratton et al. (2007) analyzed how to effectively manage a diverse team in order to overcome faultlines and reported that the two main failures in the team functioning caused by faultlines are related with collaboration and knowledge sharing. The authors concluded that team leaders and managers at the early stages of the project must focus on tasks, and when appropriate, focus on relationship building (Gratton et al., 2007).

After reviewing the literature, we are in agreement with Trezzini (2008) who opines that while there is a considerable amount of research on the faultline theory, the available indices designed to measure the strength of faultlines need to be improved to support more complex scenarios. Trezzini (2008) evaluated the validity of different faultline measures, analyzing their strengths and weaknesses, and applying them to special scenarios (Trezzini, 2008).

Therefore, as it will be discussed on Chapter 3, the different demographic diversity attributes in this study will be measured using the diversity or entropy index proposed by Teachman (1980), which is recommended to be applied on categorical variables and has been employed in several studies of diversity (Alexander et al., 1995; Jehn & Bezrukova, 2004; Jehn et al., 1999; Ting-Peng et al., 2007; Vodosek, 2007).

A list of the different diversity variables analyzed in previous research is presented in *Table 1*. The present study is extending that list to a bigger set of variables which allow us to have a better understanding of the diversity of an engineering team.

Table 1 *– Diversity Variables*

	Diversity variables		
Study	**Knowledge Diversity**	**Social Category Diversity**	**Total**
Alexander et al. (1995)	Educational Preparation, Tenure, Employment Status		3
Gibson and Vermeulen (2003)	Function, Team Tenure	Age, Sex, Ethnicity	5
Gratton et al. (2007)	Education, Work Function, Tenure (in the company)	Gender, Age, Nationality	6
Haas (2010)	Educational Level, Functional Background, Organizational Tenure, Team Tenure	Age, Gender, Ethnicity	7
Jehn and Bezrukova (2004)	Functional Background, Level of	Age, Race, Gender	6

	Education, Tenure		
Lau and Murnighan (1998)	Occupational Role	Race, Sex, Age	4
Molleman (2005)	Having a Part-Time Job	Gender, Age	3
Sakuda (2012)		Age, Nationality	2
Sampson (1984)		Race, Age	2
Shaw (2004)	Job	Gender, Age, Race	4
Thatcher et al. (2003)	Major, Work Experience, Work Function	Age, Gender, Race, Region of Origin	7
Thatcher and Patel (2011)	Function, Education Level, Team Tenure	Age, Sex, Race	6
Ting-Peng et al. (2007)	Major of Study, Education Level, Functional Area	Gender, Age	5
Vodosek (2007)	Religion, Education, Culture	Gender, Age	5
Zanutto et al. (2011)		Race, Gender, Age	3
THIS STUDY	Major, Education, Department, Years of Experience, Leadership Role	Gender, Age, Nationality, Primary Language	**9**

Finally, the main *assumption of homogeneity* for this study consists in the use of diversity indexes to measure demographic diversity variables without taking into consideration the effects of multiple diversity attributes as suggested in the Faultline theory.

2.3. Team Performance

Componation et al. (2008) provided a good definition of a "high performance team", considering it as a "small group of people with complementary skills who have a common goal and working approach, who hold themselves mutually accountable, and who are genuinely concerned for not only the success of the team but the personal growth and goals of each other" (Componation et al., 2008). This type of team is often characterized for its cohesion, they succeed or fail as a team and the team synergy is based on the strengths and limitations of team members who are totally committed to the team goal and have a deep respect and trust in each other (Componation et al., 2008).

Additionally, Componation et al. (2008) contributed important insights to the growing literature on the relationships between project success, system engineering, and team organization. According to the author, the individual processes part of the systems operations are the ones driving the effectiveness of the whole engineering project; therefore weaknesses in a few specific processes could have significant impacts on the whole project. Also, the success of the engineering team and the organization is directly influenced by the management approach implemented by team leaders and managers (Componation et al., 2008).

There have been many studies conducted on team performance measurement systems. Hacker and Lang (2000) found that a performance measurement system enhanced the performance of a virtual project team by increasing team accountability and helping to gain local management support. According to Hacker and Lang (2000), “virtual teams” are “self-managed knowledge work teams with distributed expertise that are fluid in terms of membership, leadership, and boundaries (functional, organizational, and geographical)”. The authors mentioned that the use of performance measures is consistently related with high performing teams, and the objectives of the team must be clearly defined in the early steps of the project independently of the approach used to measure team effectiveness (Hacker & Lang, 2000).

Hacker and Lang (2000) also identified common factors for high performance teams. Clearly defined goals and team members’ commitment to those goals are critical factors for successful project implementation. Team commitment has been linked to increased productivity, in fact team commitment and cohesion are mutually correlated and both have a positive relationship with team performance. (Hacker & Lang, 2000).

In the same context, Jill and Kepa (2003) proposed a performance measurement system that combines organization strategy and stakeholder view with the different drivers and dimensions of team performance (Jill & Kepa, 2003).

Martins et al. (2004) conducted a literature review of research on virtual teams, namely findings related to team inputs, processes, and outcomes. As a result of this review, the author concluded that virtual interactions increase the amount of time necessary to accomplish a task. Additionally, a virtual team produces better work, more effective decisions, higher quality ideas, and more original solutions (Martins et al., 2004).

Researchers also investigated the different factors that affect team performance and found that task work knowledge and team situational awareness are good predictors of team performance (DeFranco et al., 2011).

In a study of familiarity's role in affecting knowledge gaps in geographically dispersed teams, Assudani (2011) found that familiarity has a positive effect on the performance of a dispersed team. According to the author, a dispersed team of "familiars" can begin producing sooner because they do not need to spend time creating "transactive memory", moving more quickly to the problem solving stage. In addition, in a dispersed team of "familiars", team members have a pre-established knowledge of each other's context where daily interactions are not mandatory in order to generate knowledge. In that context, the main goal of a dispersed team must be the creation of transactive memory and the maintenance of mutual context between team members. When the dispersed team is composed by a group of strangers, at the beginning of the project, the goal of the dispersed team should be to promote personal interaction in order to encourage familiarity (Assudani, 2011).

The main findings from Assudani (2011) suggest that familiarity have critical implications in the performance of a dispersed team. Team and task familiarity contribute to the generation of knowledge structures between team members often used to reconcile misalignments. Additionally, the findings also indicate that spatial separation is not necessarily a key factor related with team collaboration and performance (Assudani, 2011).

Espinosa et al. (2012) defined “technical team performance” as “the process and product success, evidenced by its on-time completion within-budget and meeting system requirements” (Espinosa et al., 2012).

Bertels et al. (2011) studied the impact of communities of practice on the performance of dispersed teams, concluding that supporting communities of practice have a positive effect on business units. In that context, the amount of tacit knowledge in a business unit is inversely proportional to the levels of dispersed collaboration (Bertels et al., 2011).

2.4. Effects on Team Performance

Geographic Dispersion

Several authors have examined team member’s dispersion across different time zones. Massey et al. (2003) conducted a study to analyze the characteristics of team interaction and how temporal coordination can be employed when team members are communicating asynchronously in global virtual projects. The results of this study suggest that the successful application of temporal coordination mechanisms is directly associated with higher performance, mediated by task coordination. As the authors indicated, to be effective, a temporal coordination mechanism needs to be implemented in order to promote team interaction affecting positively the performance of a dispersed team (Massey et al., 2003).

Espinosa et al. (2012) proposed that spatial and temporal separation must be examined together to completely understand their impact in the performance of a team. The results of the study show that temporal dispersion has a more negative impact on team performance than spatial dispersion, mediated by coordination problems. According to the authors, the key characteristic of time separation is that it splits the working day into two sections: overlapping time and non-overlapping time. When the overlapping work time is reduced, the dispersed team is forced to conduct its tasks asynchronously. Additionally, Espinosa et al. (2012) demonstrated a relationship between temporal separation and team performance, which had not been identified before by other researchers, in this context, the bigger the time zone separation between team members the higher the effect it has on coordination problems (Espinosa et al., 2012).

A study of time allocation for geographically dispersed teams was conducted by Cummings (2012). The author found that the different levels of members' experience, position, educational background, and leadership role in the member's organization influenced time allocated to the team. According to this study, when team members are assigned a greater percentage of their time to a single team, the performance of that team is higher. Further, when team members are assigned to several teams simultaneously, the performance of those teams is also higher (Cummings & Haas, 2012).

Demographic Dispersion

Knowledge Diversity is related to differences in skills, work experience and academic background of the team members; these differences increase the likelihood of conflict. The results of a study conducted by Jehn et al. (1999) indicate a positive relationship between KD and team performance, having task conflict as a mediator of this relationship. VD and SCD were identified as moderators of this effect (Jehn et al., 1999).

Additionally, the results from Jehn et al. (1999) show that different forms of demographic diversity promote different forms of conflict which later have an effect on performance factors like perceived and actual performance, team member satisfaction, commitment and turnover rate. In this context, KD has a direct relationship with group performance, and SCD has a positive effect on the team members morale in aspects like commitment, perceived performance and satisfaction (Jehn et al., 1999).

Regarding SCD, Martins et al. (2004) found that cultural differences negatively impact team coordination and communication. Martins et al. (2004) mentioned that the asynchronous communication in a dispersed team may cause team members having to work on multiple tasks at the same time; therefore their focus of attention may not be just the team's task. Additionally, as the author mentions, previous research has not demonstrated that virtual teams require less effort than collocated teams (Martins et al., 2004).

Ting-Peng et al. (2007) conducted a study to analyze the effects of Knowledge, Social Category, and Value Diversity on software project performance. The results show that KD positively affects team performance, mediated by task conflict; therefore, team leaders and global managers can rely on knowledge differences between team members in order to achieve a higher team performance. Additionally, VD negatively affects team performance, mediated by relationship conflict, which is why team leaders of dispersed teams must work to minimize the diversity of values and ideas among team members. Finally, the authors found that the relation between SCD and performance is mixed (Ting-Peng et al., 2007).

Daim et al. (2012) conducted a study to investigate the types of factors that contribute to a communication breakdown in globally virtual teams. According to the author, the overall performance for a geographically dispersed team can be affected by cultural differences like language barriers. There are unique cultural differences affecting the overall performance of a dispersed team with team members located across different countries, for instance, language barriers can cause misunderstandings and differences in expectations between team members with a profound impact on the overall performance or the dispersed engineering team. Additionally, cultural differences might cause communication issues related with factors like functional disciplines of team members, organizational structure, the nationalities of the group members, and the country in which the team is located (Daim et al., 2012).

Research Hypothesis

This study argues that geographic and demographic dispersion variables have an effect on the performance of a dispersed team along each phase of the engineering life cycle and posits the following six hypotheses:

Hypothesis 1 (H1): Geographic and Demographic Dispersion variables are related with the performance of a SE Team during the **Concept** phase.

Hypothesis 2 (H2): Geographic and Demographic Dispersion variables are related with the performance of a SE Team during the **Development** phase.

Hypothesis 3 (H3): Geographic and Demographic Dispersion variables are related with the performance of a SE Team during the **Production** phase.

Hypothesis 4 (H4): Geographic and Demographic Dispersion variables are related with the performance of a SE Team during the **Utilization** phase.

Hypothesis 5 (H5): Geographic and Demographic Dispersion variables are related with the performance of a SE Team during the **Support** phase.

Hypothesis 6 (H6): Geographic and Demographic Dispersion variables are related with the performance of a SE Team during the **Retirement** phase.

In summary, it can be hypothesized that geographic and demographic dispersion will affect SE team performance. These hypotheses are related to both research questions proposed for this study in Chapter 1, and are shown in *Figure 2* as part of the Research Model, where N is the total number of team members assigned to the project, and n_k is the total number of team members assigned to each one of the k sites.

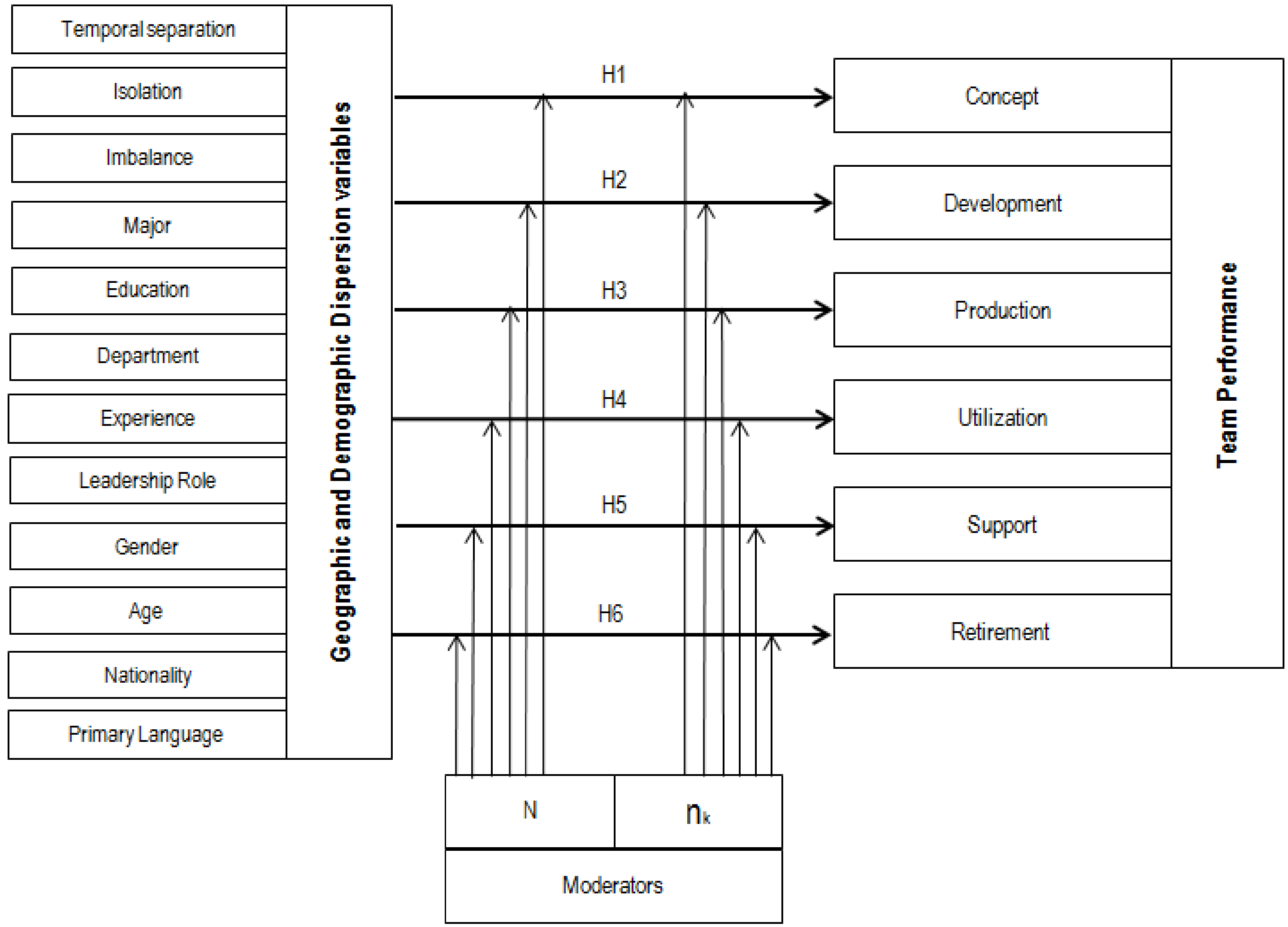

***Figure 2** - Research Model*

Chapter 3 - Variables Measurement and Data Collection

According to the research model proposed in *Figure 2*, there are three groups of variables to be analyzed in this study: geographic dispersion, demographic dispersion, and team performance. Their measurement and indicators are described below.

3.1.Geographic Dispersion

The literature shows four indexes associated with the critical dimensions of geographic dispersion: Space and Distance Index (SDI), which is related to spatial separation; Time Zone Index (TZI), which is related to temporal separation; and, Isolation Index and Imbalance index both related to configurational separation (O'Leary & Cummings, 2007).

The SDI is calculated using the geodesic distances between the different sites where the team members were located, considering the number of members located at each site and a matrix of all possible and non-redundant connections between the sites where team members are located. The higher the SDI, the more spatially dispersed the team (O'Leary & Cummings, 2007). The formula for SDI is presented in *Table 2*.

Table 2 *- Spatial Distance Index - (O'Leary & Cummings, 2007)*

$$SDI = \frac{\sum_{q}^{m}(Miles_q * n_{q1} * n_{q2})}{(N^2 - N)/2}$$

where:

m = total of possible and non-redundant connections between sites

$Miles_q$ = miles between sites in the connection q

n_{q1} and n_{q2} = number of members in sites q_1 and q_2, under connection q

N = number of team members across all sites

Even though SDI is a recognized index in the literature, we are not including it into the analysis for this study. As mentioned in previous research, daily contact among team members is significantly reduced when they are separated by more than 30 meters from each other (Kirkman & Mathieu, 2005). Therefore, it is our understanding that for a group of team members, when they are spatially separated by more than 30 meters, it does not matter if the distance between them is 100 miles or 1000 miles.

The TZI captures the overlapping time when members can interact synchronously. Its calculation is similar to the SDI, through a matrix of all possible and non-redundant connections between the sites where team members are located (O'Leary & Cummings, 2007). The formula for TZI is presented in *Table 3*.

Table 3 *– Time Zone Index - (O'Leary & Cummings, 2007)*

$$TZI = \frac{\sum_{q}^{m}(TimeZones_q * n_{q1} * n_{q2})}{(N^2 - N)/2}$$

where:

m = total of possible and non-redundant connections between sites

$TimeZones_q$ = time zones between sites in the connection q

n_{q1} and n_{q2} = number of members in sites q_1 and q_2, under connection q

N = number of team members across all sites

In order to calculate the TZI index for a randomly selected project in this study, we need to take into consideration all possible combinations of two cities and calculate the time zone difference between them. One example of the calculation of the TZI index is presented in *Table 4*, when we are considering a project conducted among three cities: Barcelona (three team members), Berlin (one team member), and Bogota (one team member).

Table 4 ***–*** *TZI calculation - Example*

CITY 1	CITY 2	TZ 1	TZ 2	TZ Difference	n1	n2	TZ(n1-n2)	TZI
Bogota, Colombia	Barcelona, Spain	-5	1	6	1	3	6	18
Bogota, Colombia	Berlin, Germany	-5	1	6	1	1	6	6
Barcelona, Spain	Berlin, Germany	1	1	0	3	1	0	0

TZI = 18 + 6 + 0 = 24

The isolation index measures the proportion of team members assigned to a site where there are no other team members. The higher the isolation index, the more the isolation affects the team (O'Leary & Cummings, 2007). The formula to calculate the Isolation Index is presented in *Table 5*.

Table 5 **–** *Isolation Index - (O'Leary & Cummings, 2007)*

$\frac{Total_{isolated}}{N}$	where: $Total_{isolated}$ = Number of sites with only one team member assigned N = number of team members across all sites

As an example of the calculation of the isolation index, the *Table 6* presents the results taking in consideration the same project analyzed in *Table 4*, with team members dispersed among three cities.

Table 6 **–** *Isolation Index calculation - Example*

	n_k
Bogota, Colombia	1
Barcelona, Spain	3
Berlin, Germany	1

Isolation Index = 2/5 = 0.4

The imbalance index represents how balanced or imbalanced is the team configuration, where imbalanced configurations may derive in majority-minority and subgroup effects (O'Leary & Cummings, 2007). The formula to calculate the Isolation index is presented in *Table 7*.

Table 7 **–** *Imbalance Index - (O'Leary & Cummings, 2007)*

$\frac{\sigma(n_i, n_j, \dots, n_k)}{N}$	Where: k is the total number of sites n_i and n_j = number of members in sites i and j N = number of team members across all sites

Taking into consideration the same project analyzed in *Table 6*, with team members distributed in three subgroups, the result of the calculation of the imbalance index is equal to **0.23**.

3.2.Demographic Dispersion

As mentioned in *Table 1*, this study adopted five criteria to measure KD: **major of study, level of education, functional department, years of experience**, and **leadership role**.

Because these items are categorical variables, based on Ting-Peng et al. (2007), this study uses the entropy-based index in order to calculate an aggregated measure for each KD criterion, considering how many categories or different values each one of them has. The formula for KD is presented in *Table 8* (Ting-Peng et al., 2007).

***Table 8** – Knowledge Diversity - (Ting-Peng et al., 2007)*

$KD = -\sum_{i=1}^{n} P_i(\ln P_i)$	where: P_i = fraction of members falling into category i n = number of categories (possible values) ln = natural logarithm Sum of all values for P_i is equal to 1

The *Table 9* presents the results of the calculation of the KD index for a randomly selected project and the percentage of users which belong to each one of the criteria: major of study, level of education, functional department, years of experience, and leadership role.

***Table 9** – KD calculation - Example*

MAJOR

CATEGORIES	**PERCENTAGE**	**FORMULA**
Telecommunications	0.25	-0.34657359
Economy	0.25	-0.34657359
Industrial	0.25	-0.3466
Computer Science	0.25	-0.3466
	Major	1.3863

EDUCATION LEVEL

CATEGORIES	PERCENTAGE	FORMULA
BS	0.5	-0.3466
MS	0.5	-0.3466
	Education	0.6931

FUNCTIONAL

DEPARTMENT

CATEGORIES	PERCENTAGE	FORMULA
Technology	0.75	-0.2158
Insurance	0.25	-0.3466
	Department	0.5623

EXPERIENCE

CATEGORIES	PERCENTAGE	FORMULA
From 1 to 5 years	0.5	-0.3466
From 6 to10 years	0.25	-0.3466
From 11 to15 years	0.25	-0.3466
	Experience	1.0397

LEADERSHIP ROLE

CATEGORIES	PERCENTAGE	FORMULA
Y	0.5	-0.3466
N	0.5	-0.3466
	Leadership	0.6931

Major = 1.3863 Education = 0.6931 Department = 0.5623 Experience = 1.0397 Leadership = 0.6931

Based on *Table 1*, in order to measure SCD this study adopted four criteria: **gender, age, nationality** and **primary language**. Because these items are categorical, entropy-based index is used to measure SCD (Ting-Peng et al., 2007). The formula for SCD is presented in *Table 10*.

Table 10 ***–*** *Social Category Diversity - (Ting-Peng et al., 2007)*

$$\mathrm{SCD} = -\sum_{i=1}^{n} P_i(\ln P_i)$$	where: P_i = fraction of members falling into category i n = number of categories, possible values for category i Sum of all values for P_i is equal to 1

The *Table 11* presents the results of the calculation of the SCD index for the same project selected for the calculation of the KD index, including the percentage of users which belong to each one of the SCD criteria: gender, age, nationality and primary language.

Table 11 *– SCD calculation - Example*

GENDER

CATEGORIES	**PERCENTAGE**	**FORMULA**
Female	0.25	-0.3466
Male	0.75	-0.2158
	Gender	0.5623

AGE

CATEGORIES	**PERCENTAGE**	**FORMULA**
From 20 to 30	0.5	-0.3466
From 30 to 40	0.5	-0.3466
	Age	0.6931

NATIONALITY

CATEGORIES	**PERCENTAGE**	**FORMULA**
Swiss	0.5	-0.3466
Spanish	0.5	-0.3466
	Nationality	0.6931

PRIMARY

LANGUAGE

CATEGORIES	**PERCENTAGE**	**FORMULA**
German	0.5	-0.3466
Spanish	0.5	-0.3466
	Language	0.6931

Gender = 0.5623 Age = 0.6931 Nationality = 0.6931 Language = 0.6931

3.3.Team Performance

Data about the SE team performance was collected using a questionnaire which consisted of a set of questions (two for each phase of the SE life cycle) to be answered by each one of the team leaders. While a measurement of perception, previous research indicates that managers' evaluation of team performance sufficiently correlates to actual measured performance (Higgs et al., 2005).

Questions were answered using a five-point Likert scale with values varying from 1 - "Strongly Disagree" to 5 - "Strongly Agree":

- The quality of the deliverables was excellent.
- The deliverables were completed on time.

3.4. Data Collection

A single questionnaire form was distributed to team leaders of SE teams in order to collect data about geographic and demographic dispersion and team performance. Participants of this research included professionals in the fields of information technology and civil engineering from firms located among different American, Asian, and European countries. The following criteria for selecting sample SE projects were proposed in order to ensure data validity:

- It should be a SE project
- Team members must have experienced either geographic or demographic dispersion
- The system must be at least in the production and maintenance life cycle phases
- Project manager must be available to complete the questionnaire

The data collection process was conducted between January 2013 and July 2013. One questionnaire was distributed to each one of the 47 team leaders of 106 identified projects. Responses were received from 19 team leaders corresponding to a total of 30 projects geographically distributed among 57 cities in 38 countries, having team members located in a total of 247 sites. Thus, the response rate was 40 percent at the individual level and 28 percent at the project level.

Figure 3 shows the total of countries per continent where the identified projects are present on one or more sites. Note that the North American category contains the Central-American and Caribbean countries.

The majority of the respondents (63.15 percent) were males, and most of them (94.7 percent) had an educational background in Information Technology. Their education ranged from bachelors in science to doctoral degrees.

Figure 4 shows the percentage of projects classified by Industry. According to the data collection process results, 67% of the projects are related with software development and therefore have a high level of virtualness, with team members relying on virtual communication technology to perform their daily operations. Virtual communication tools include a vast arrange of technologies/products to conduct videoconferences, virtual meetings, chats, forums, communities of practice, among others.

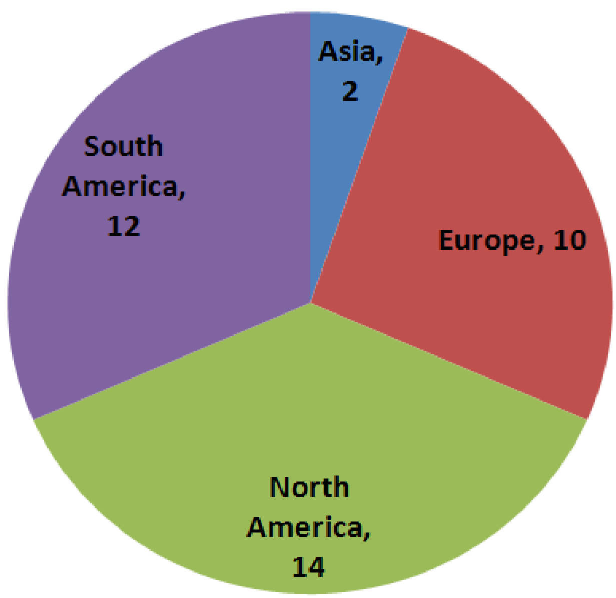

Figure 3 *- Total of countries per continent with identified projects*

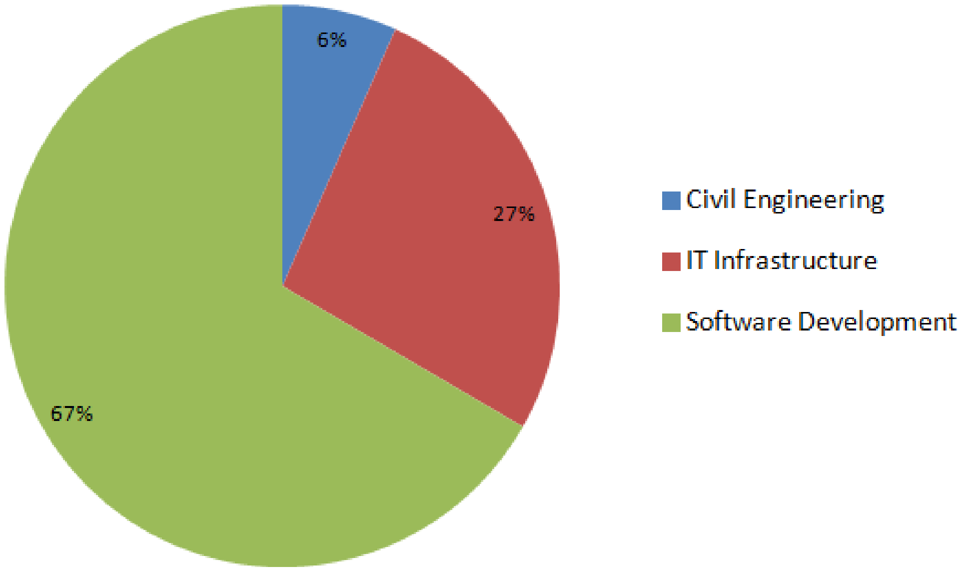

Figure 4 *- Percentage of identified projects by Industry*

Chapter 4 - Data Analysis and Results

Multiple linear regression (MLR) was selected as data analysis technique for this study. MLR was conducted in order to determine the type of relationship between dispersion and performance variables.

4.1. Multiple Linear Regression

Multiple linear regression is used to analyze the relationship between a set of independent variables and a single dependent variable, allowing researchers to determine the type of relationship between the variables, the statistical significance of the relationship, and also how well the model generalizes to observations outside the sample (Lattin, 2003). Important outputs from MLR are the estimated model coefficients, which allow linking a dependent variable with several independent variables in an equation, as shown in *Table 12*.

Table 12 *– MLR estimated model coefficients (Lattin, 2003)*

$$Vd = \boldsymbol{\beta_0} + \boldsymbol{\beta_1} V_{i1} + \boldsymbol{\beta_2} V_{i2} \dots + \boldsymbol{\beta_n} V_{in}$$

where:

Vd is the dependent variable;

β_0, β_1,…,β_n are estimated model coefficients;

$V_1, V_2, \ldots, V_n$ are descriptors of the independent variables;

n is the number of independent variables

In the case of this study, five MLR exercises were conducted with five equations used to analyze the relationship between independent variables (concept, development, production, utilization and support) and dependent variables (N, n_k, TZI, Isolation, Imbalance, Major, Education, Department, Experience, Leadership, Gender, Age, Nationality and Language), as shown in *Table 13*.

Table 13 ***–*** *MLR equations*

Concept = $\boldsymbol{\beta_0}$ + $\boldsymbol{\beta_1}$(n) + $\boldsymbol{\beta_2}$(n_k) + $\boldsymbol{\beta_3}$(TZI) + $\boldsymbol{\beta_4}$(Isolation) + $\boldsymbol{\beta_5}$(Imbalance) + $\boldsymbol{\beta_6}$(Major) + $\boldsymbol{\beta_7}$(Education) + $\boldsymbol{\beta_8}$(Department) + $\boldsymbol{\beta_9}$(Experience) + $\boldsymbol{\beta_{10}}$(Leadership) + $\boldsymbol{\beta_{11}}$(Gender) + $\boldsymbol{\beta_{12}}$(Age) + $\boldsymbol{\beta_{13}}$(Nationality) + $\boldsymbol{\beta_{14}}$(Language)

Development = $\boldsymbol{\beta_0}$ + $\boldsymbol{\beta_1}$(n) + $\boldsymbol{\beta_2}$(n_k) + $\boldsymbol{\beta_3}$(TZI) + $\boldsymbol{\beta_4}$(Isolation) + $\boldsymbol{\beta_5}$(Imbalance) + $\boldsymbol{\beta_6}$(Major) + $\boldsymbol{\beta_7}$(Education) + $\boldsymbol{\beta_8}$(Department) + $\boldsymbol{\beta_9}$(Experience) + $\boldsymbol{\beta_{10}}$(Leadership) + $\boldsymbol{\beta_{11}}$(Gender) + $\boldsymbol{\beta_{12}}$(Age) + $\boldsymbol{\beta_{13}}$(Nationality) + $\boldsymbol{\beta_{14}}$(Language)

Production = $\boldsymbol{\beta_0}$ + $\boldsymbol{\beta_1}$(n) + $\boldsymbol{\beta_2}$(n_k) + $\boldsymbol{\beta_3}$(TZI) + $\boldsymbol{\beta_4}$(Isolation) + $\boldsymbol{\beta_5}$(Imbalance) + $\boldsymbol{\beta_6}$(Major) + $\boldsymbol{\beta_7}$(Education) + $\boldsymbol{\beta_8}$(Department) + $\boldsymbol{\beta_9}$(Experience) + $\boldsymbol{\beta_{10}}$(Leadership) + $\boldsymbol{\beta_{11}}$(Gender) + $\boldsymbol{\beta_{12}}$(Age) + $\boldsymbol{\beta_{13}}$(Nationality) + $\boldsymbol{\beta_{14}}$(Language)

Utilization = $\boldsymbol{\beta_0}$ + $\boldsymbol{\beta_1}$(n) + $\boldsymbol{\beta_2}$(n_k) + $\boldsymbol{\beta_3}$(TZI) + $\boldsymbol{\beta_4}$(Isolation) + $\boldsymbol{\beta_5}$(Imbalance) + $\boldsymbol{\beta_6}$(Major) + $\boldsymbol{\beta_7}$(Education) + $\boldsymbol{\beta_8}$(Department) + $\boldsymbol{\beta_9}$(Experience) + $\boldsymbol{\beta_{10}}$(Leadership) + $\boldsymbol{\beta_{11}}$(Gender) + $\boldsymbol{\beta_{12}}$(Age) + $\boldsymbol{\beta_{13}}$(Nationality) + $\boldsymbol{\beta_{14}}$(Language)

Support = $\boldsymbol{\beta_0}$ + $\boldsymbol{\beta_1}$(n) + $\boldsymbol{\beta_2}$(n_k) + $\boldsymbol{\beta_3}$(TZI) + $\boldsymbol{\beta_4}$(Isolation) + $\boldsymbol{\beta_5}$(Imbalance) + $\boldsymbol{\beta_6}$(Major) + $\boldsymbol{\beta_7}$(Education) + $\boldsymbol{\beta_8}$(Department) + $\boldsymbol{\beta_9}$(Experience) + $\boldsymbol{\beta_{10}}$(Leadership) + $\boldsymbol{\beta_{11}}$(Gender) + $\boldsymbol{\beta_{12}}$(Age) + $\boldsymbol{\beta_{13}}$(Nationality) + $\boldsymbol{\beta_{14}}$(Language)

Where:

N is the total number of team members;

n_k is the total number of team members assigned to the site k;

TZI, Isolation and Imbalance correspond to Geographic Diversity indexes;

Major, Education, Department, Experience, Leadership, Gender, Age, Nationality and Language correspond to Demographic Diversity indexes;

Note that for MLR, the Retirement phase of the SE life cycle was not considered because only 26.66 percent of the projects included in this study reached that phase.

MLR was conducted in a sample size with 247 observations, where each observation corresponds to the 247 sites that belong to the 30 identified projects. Before conducting MLR, the data was transformed to achieve normality, using IBM SPSS Statistics v21.0.0. The measures of skewness and kurtosis are shown in *Table 14* and indicate the data was approximately normally distributed.

Table 14 *- Skewness and Kurtosis values (n=247)*

	Skewness	**Kurtosis**	**Transformation**
N	0.504	-1.182	COMPUTE N = SQRT(37 - N)
n_k	-1.442	0.397	COMPUTE n_k = 1/k
TZI	1.011	3.962	COMPUTE TZI=1/(TZI+1)
Isolation	0.968	-0.767	COMPUTE Isolation=LG10(2-Isolation)
Imbalance	-.771	-.587	COMPUTE Imbalance=1/(Imbalance +0.1)
Major	.707	-.121	COMPUTE Major = SQRT(Major)
Education	.953	3.799	COMPUTE Education = SQRT(1.09 + 1 – Education)
Department	.299	-.578	COMPUTE Department = SQRT(Department)
Experience	-.576	.580	
Leadership	.009	-1.711	
Gender	-1.463	2.334	COMPUTE Gender = 1/(1.69 - Gender)
Age	.183	-.174	
Nationality	-.980	-.709	
Language	-.420	1.899	COMPUTE Language = 1/(2.35 - Language)

To ensure the validity of MLR results, a multicollinearity test was conducted along each one of the five MLR exercises, with no evidence of multicollinearity issues. Multicollinearity occurs when two or more independent variables are highly correlated with each other, which cause difficulties when determining the contribution of a single variable to the variance explained ("Laerd Statistics," 2013).

Additional tests were conducted in order to detect outliers and to check for leverage and influential points, where no cases were found. Results from the MLR, including the model summaries and regression coefficients, are presented in Tables 15, 16, 17, 18 and 19, while ANOVA results are shown in Tables 20, 21, 22, 23 and 24.

Table 15 **-** *Summary of Linear Regressions predicting Concept*

	Dependent variable: Concept				
	R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	
	0.870	**0.756**	**0.743**	.24090	
	Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	2.844	.300		9.471	.000
N	.429	.029	1.394	14.532	.000
n_k	.153	.077	.090	1.998	.047
TZI	-.913	.182	-.269	-5.027	.000
Isolation	-2.515	.455	-.566	-5.524	.000
Imbalance	.053	.014	.239	3.689	.000
Department	.821	.065	.628	12.610	.000
Experience	.894	.125	.422	7.171	.000
Leadership	.420	.113	.178	3.713	.000
Gender	-.992	.280	-.161	-3.544	.000
Age	-1.275	.113	-.497	-11.280	.000
Nationality	.435	.063	.948	6.950	.000
Language	-.766	.294	-.170	-2.608	.010

Table 16 - *Summary of Linear Regressions predicting Development*

	Dependent variable: Development				
	R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	
	0.935	**0.875**	**0.871**	.31457	
	Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	5.196	.291		17.855	.000
N	.226	.037	.399	6.155	.000
Isolation	-5.440	.480	-.664	-11.338	.000
Imbalance	-.029	.015	-.072	-2.005	.046
Major	1.389	.081	.567	17.132	.000
Age	-3.277	.126	-.692	-26.093	.000
Nationality	.653	.073	.771	9.005	.000
Language	-.561	.234	-.068	-2.397	.017

Table 17 *- Summary of Linear Regressions predicting Production*

	Dependent variable: Production				
	R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	
	0.957	**0.916**	**0.912**	.20637	
	Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	6.439	.295		21.846	.000
N	-.376	.027	-.835	-14.084	.000
TZI	1.271	.151	.256	8.392	.000
Imbalance	-.155	.013	-.478	-12.356	.000
Major	1.601	.067	.824	23.756	.000
Department	-.319	.058	-.167	-5.505	.000
Experience	.607	.105	.196	5.796	.000
Leadership	1.561	.106	.452	14.742	.000
Gender	-.644	.227	-.071	-2.837	.005
Age	-2.119	.097	-.564	-21.904	.000
Nationality	.377	.043	.561	8.808	.000
Language	-1.291	.248	-.196	-5.202	.000

Table 18 *- Summary of Linear Regressions predicting Utilization*

	Dependent variable: Utilization				
	R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	
	0.899	**0.809**	**0.800**	.20531	
	Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	4.586	.291		15.777	.000
N	.214	.027	.720	8.059	.000
TZI	-.680	.140	-.207	-4.863	.000
Isolation	-6.550	.353	-1.527	-18.571	.000
Imbalance	.095	.012	.440	7.753	.000
Major	.740	.066	.577	11.221	.000
Department	.823	.060	.652	13.805	.000
Leadership	-1.462	.107	-.642	-13.727	.000
Gender	1.422	.241	.239	5.894	.000
Age	-.726	.087	-.293	-8.352	.000
Nationality	-.304	.050	-.687	-6.032	.000
Language	-.915	.197	-.211	-4.647	.000

Table 19 *- Summary of Linear Regressions predicting Support*

	Dependent variable: Support				
	R	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**	
	0.807	**0.652**	**0.641**	.38080	
	Unstandardized Coefficients		**Standardized Coefficients**	**t**	**Sig.**
	B	**Std. Error**	**Beta**		
(Constant)	2.872	.661		4.345	.000
N	.168	.023	.409	7.304	.000
Education	2.167	.418	.267	5.190	.000
Department	-.357	.079	-.204	-4.515	.000
Experience	1.476	.182	.521	8.095	.000
Leadership	-2.241	.171	-.709	-13.112	.000
Age	-2.093	.168	-.609	-12.422	.000
Language	-1.455	.328	-.242	-4.438	.000

Table 20 - *ANOVA - Concept*

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	40.104	12	3.342	57.590	.000[b]
Residual	12.941	223	.058		
Total	53.046	235			

a. Dependent Variable: Concept

b. Predictors: (Constant), Leadership, Gender, Age, n_k, Experience, N, Nationality, Department, Isolation, TZI, Imbalance, Language

Table 21 - *ANOVA - Development*

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	157.882	7	22.555	227.932	.000[b]
Residual	22.561	228	.099		
Total	180.444	235			

a. Dependent Variable: Development

b. Predictors: (Constant), Isolation, Age, Major, Nationality, N, Language, Imbalance

Table 22 *- ANOVA - Production*

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	104.019	11	9.456	222.036	.000[b]
Residual	9.540	224	.043		
Total	113.559	235			

a. Dependent Variable: Production

b. Predictors: (Constant), Major, N, Age, Leadership, TZI, Imbalance, Nationality, Gender, Department, Experience, Language

Table 23 *- ANOVA - Utilization*

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	39.995	11	3.636	86.259	.000[b]
Residual	9.442	224	.042		
Total	49.436	235			

a. Dependent Variable: Utilization

b. Predictors: (Constant), Isolation, N, Department, Gender, Leadership, Major, Age, Imbalance, Nationality, TZI, Language

Table 24 *- ANOVA - Support*

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	61.933	7	8.848	61.015	.000[b]
Residual	33.062	228	.145		
Total	94.995	235			

a. Dependent Variable: Support

b. Predictors: (Constant), Age, Leadership, N, Experience, Education, Department, Language

The results in Tables 15, 16, 17, 18 and 19 show that multiple correlation coefficients R, which can be considered as a measure of the quality of the prediction of the dependent variables, indicate a good level of prediction for the performance of a dispersed team along each one of the phases under analysis. Additionally, the adjusted R squared (adj. R^2) values, which represent the proportion of variance in the dependent variable that can be explained by the independent variables, show that dispersion variables have a large effect on the variance of the team performance along each one of the phases under analysis. MLR resulting coefficients are summarized in *Table 25*.

The results in Tables 20, 21, 22, 23 and 24 show that the independent variables statistically significantly predict each dependent variable, as is summarized in *Table 26*.

Table 25 *– MLR Regression coefficients*

Phase	**R**	R^2	$AdjR^2$
Concept	0.870	0.756	0.743
Development	0.935	0.875	0.871
Production	0.957	0.916	0.912
Utilization	0.899	0.809	0.800
Support	0.807	0.652	0.641

Table 26 *– MLR Significance results*

Phase	**Significance results**
Concept	$F(12, 223) = 57590, p < .0005$
Development	$F(7, 228) = 227.932, p < .0005$
Production	$F(11, 224) = 222.036, p < .0005$
Utilization	$F(11, 224) = 86.259, p < .0005$
Support	$F(7, 228) = 61.015, p < .0005$

The resulting equations for team performance, using unstandardized coefficients and based on geographic and demographic variables, are listed in *Table 27*.

Table 27 *– MLR equations - results*

Concept = 2.844 + 0.429**(N)** + 0.153**(n_k)** - 0.913**(TZI)** - 2.515**(Isolation)** + 0.053**(Imbalance)** + 0.821**(Department)** + 0.894**(Experience)** + 0.42**(Leadership)** -

0.992**(Gender)** - 1.275**(Age)** + 0.435**(Nationality)** - 0.766**(Language)**

Development = 5.196 + 0.226**(N)** - 5.44**(Isolation)** - 0.029**(Imbalance)** + 1.389**(Major)** - 3.277**(Age)** + 0.653**(Nationality)** - 0.561**(Language)**

Production = 6.439 - 0.376**(N)** + 1.271**(TZI)** - 0.155**(Imbalance)** + 1.601**(Major)** - 0.319**(Department)** + 0.607**(Experience)** + 1.561**(Leadership)** - 0.644**(Gender)** - 2.119**(Age)** + 0.377**(Nationality)** -1.291**(Language)**

Utilization = 4.586 + 0.214**(N)** - 0.68**(TZI)** - 6.55**(Isolation)** + 0.095**(Imbalance)** + 0.74**(Major)** + 0.823**(Department)** - 1.462**(Leadership)** + 1.422**(Gender)** - 0.726**(Age)** - 0.304**(Nationality)** - 0.915**(Language)**

Support = 2.872 + 0.168**(N)** + 2.167**(Education)** - 0.357**(Department)** + 1.476**(Experience)** - 2.241**(Leadership)** - 2.093**(Age)** - 1.455**(Language)**

Where:

N is the total number of team members;

$\mathbf{n_k}$ is the total number of team members assigned to the site k;

TZI, **Isolation** and **Imbalance** correspond to Geographic Diversity indexes;

Major, **Education**, **Department**, **Experience**, **Leadership** (Leadership role), **Gender**, **Age**, **Nationality** and **Language** (Primary Language) correspond to Demographic Diversity indexes;

Chapter 5 - Conclusions, Limitations, and Recommendations

The main objective of this research study was to determine how geographic and demographic dispersion affect the performance of a SE team along each phase of the SE life cycle, and which dispersion factors have more influence on the performance of an SE team for each life cycle phase. The results of this study constitute important information for systems engineers and global team managers.

To achieve these objectives, a multiple regression analysis was run for each SE life cycle phase to predict team performance (dependent variable) based on geographic and demographic variables (independent variables) such as Isolation, Imbalance, Major, Education, Department, Experience, among others. The results of MLR show that independent variables statistically significantly predicted team performance along each phase of the SE life cycle, except for the Retirement phase. MLR results are presented in Tables 15 to 27.

Hypothesis 1 was supported according to the MLR results. For the **Concept phase**, the following twelve variables: **N** (total number of team members), $\mathbf{n_k}$ (total number of team members per site), **TZI** (Time Zone Index), **Isolation**, **Imbalance**, **Department**, **Experience**, **Leadership Role**, **Gender**, **Age**, **Nationality** and **Primary Language**, all added statistically significantly to the prediction, $p < .05$. From these results, we can determine that the dispersion factors with a high influence on team performance during the Concept phase are Isolation (negative relationship) and Age (negative relationship).

Hypothesis 2 was supported according to the MLR results. For the **Development phase**, the following seven variables: **N** (total number of team members), **Isolation**, **Imbalance**, **Major**, **Age**, **Nationality** and **Primary Language**, all added statistically significantly to the prediction, $p < .05$. From these results, we can determine that the dispersion factors with a high influence on team performance during the Development phase are Isolation (negative relationship) and Age (negative relationship).

Hypothesis 3 was supported according to the MLR results. For the **Production phase**, the following eleven variables: **N** (total number of team members), **TZI** (Time Zone Index), **Imbalance**, **Major**, **Department**, **Experience**, **Leadership Role**, **Gender**, **Age**, **Nationality** and **Primary Language**, all added statistically significantly to the prediction, $p < .05$. From these results, we can determine that the dispersion factors with a high influence on team performance during the Production phase are Major (positive relationship) and Age (negative relationship).

Hypothesis 4 was supported according to the MLR results. For the **Utilization phase**, the following eleven variables: **N** (total number of team members), **TZI** (Time Zone Index), **Isolation**, **Imbalance**, **Major**, **Department**, **Leadership Role**, **Gender**, **Age**, **Nationality** and **Primary Language**, all added statistically significantly to the prediction, $p < .05$. From these results we can determine that the dispersion factors with a high influence on team performance during the Utilization phase are Isolation (negative relationship) and Leadership Role (negative relationship).

Hypothesis 5 was supported according to the MLR results. For the **Support phase**, the following seven variables: **N** (total number of team members), **Education, Department**, **Experience**, **Leadership Role**, **Age** and **Primary Language**, all added statistically significantly to the prediction, $p < .05$. From these results we can determine that the dispersion factors with a high influence on team performance during the Support phase are Education (positive relationship) and Leadership Role (negative relationship).

As previously mentioned, we were unable to obtain MLR results for the Retirement phase because of the low amount of data collected about team performance for that phase (only 26.66% of the identified projects have reached the Retirement phase at the time of data collection). Therefore, Retirement phase was excluded from our analysis and we cannot support or reject **Hypothesis 6**.

It is important to mention that, according to the results of this study, Age and Primary Language are the Demographic Dispersion factors that added statistically significantly to the prediction of team performance during all phases of the SE Life Cycle.

5.1.Limitations and Recommendations

There are several limitations to this research; the main one being related to the number of observations (n=30), which is caused in part because of the difficulty to collect this kind of information (companies are not always willing to provide demographic information about its employees such as gender, nationality, and age).

Considering that we have identified for each SE Life Cycle phase the Geographic and Demographic dispersion factors that are the higher predictors of team performance, team leaders and managers of dispersed engineering teams must pay special attention to those factors during the administration of team composition.

A future research avenue could explore the relationship between geographic and demographic dispersion with team performance, taking into consideration the possible changes in team composition during the different phases of the SE life cycle, and also scenarios where team members are reporting to different projects simultaneously with competing priorities.

Future research could also consider including into the analysis different factors that have been identified as moderators of the effects of Team Dispersion over Team Performance -- factors such as communication technology and the perceived dispersion mitigated by the use of that technology, knowledge creation and sharing, and team coordination.

Additionally, future research should take into consideration the measuring of faultlines as a way to incorporate into the analysis the simultaneous effects on team performance caused by multiple diversity attributes.

Finally, future research could also investigate scenarios with non-linear, asymptotic effects between geographic and temporal dispersion variables and their effects on the performance of engineering teams.

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APPENDIX A

Data Collection Form

THE GEORGE WASHINGTON UNIVERSITY

GWU Research

Effects of geographic and demographic dispersion on the performance of System Engineering Teams

Data Collection Form

Marco Segura

12/20/2012

Geographic Dispersion

What was the purpose of your project?

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

For each geographic location where the team members were located during the project, indicate the address and the number of team members:

Site ID	Address	Number of team members
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Demographic Dispersion

Knowledge Diversity

For each team member of your team, specify the following information:

Team Member ID	Site ID	Major	Education	Department	Years of Experience	Leadership Role
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						

16						
17						
18						
19						
20						
21						
22						
23						
24						
25						

- Major: Namely major of study
- Education: Level of Education
- Department: Functional area of work
- Years of Experience: Company Experience - Years of experience in the company
- Leadership role: Is the team member performing as team leader? Y/N

Social Category Diversity

For each team member of your team, specify the following information:

Team Member ID	**Site ID**	**Gender**	**Age**	**Nationality**	**Primary Language**

1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					

24					
25					

- Gender: M/F
- Age
- Nationality
- Primary Language

Systems Engineering Team Performance

For each phase of the Systems Engineering Life Cycle, specify the values for each one of the following questions:

Concept

a) **The quality of the deliverables is excellent.**

o o o o o

Strongly disagree Strongly agree

b) **The deliverables were completed on time.**

o o o o o

Strongly disagree Strongly agree

Development

a) **The quality of the deliverables is excellent.**

o o o o o

Strongly disagree Strongly agree

b) **The deliverables were completed on time.**

o o o o o

Strongly disagree Strongly agree

Production

a) **The quality of the deliverables is excellent.**

o o o o o

Strongly disagree Strongly agree

b) **The deliverables were completed on time.**

o o o o o

Strongly disagree Strongly agree

Utilization

a) **The quality of the deliverables is excellent.**

o o o o o

Strongly disagree Strongly agree

b) The deliverables were completed on time.

o o o o o

Strongly disagree Strongly agree

Support

a) The quality of the deliverables is excellent.

o o o o o

Strongly disagree Strongly agree

b) The deliverables were completed on time.

o o o o o

Strongly disagree Strongly agree

Retirement

a) The quality of the deliverables is excellent.

o o o o o

Strongly disagree Strongly agree

b) The deliverables were completed on time.

o o o o o

Strongly disagree Strongly agree

APPENDIX B

Information Sheet about the Research Study

Information Sheet about the Research Study

“Effects of geographic and demographic dispersion on the performance of System Engineering Teams”

IRB # 121237

You are invited to participate in a research study under the direction of Dr. Thomas Mazzuchi (email: mazzu@gwu.edu; phone number: (###) ### - ####) of the Department of Engineering Management and Systems Engineering, George Washington University (GWU). Taking part in this research is entirely voluntary.

The purpose of this study is to analyze the effects of geographic and demographic dispersion on the performance of systems engineering teams, determining how dispersion influence the capacity of those teams to deliver the desired results in each phase of the systems engineering life cycle, and identifying which phases of the SE Life Cycle are more susceptible to positive or negative effects caused by team dispersion.

If you choose to take part in this study, you will be maintaining discussions in person or remotely with the Research Team, where questionnaires and surveys are going to be employed as data collection mechanisms. The research team will ask questions about the structure of the engineering teams, the roles and profiles of team members, and the performance of the teams along the different phases of the project. The total amount of time you will spend in connection with this study is approximately between 2 to 4 hours.

You may refuse to participate in the proposed discussions and you may stop your participation in this study at any time.

You will not benefit directly from your participation in the study. The benefits to science and humankind that might result from this study are: Information about the effects of dispersion along the different phases of the engineering life cycle will help to mitigate risks related to dispersion and also take advantages of the opportunities that geographic and demographic dispersion present to system engineering teams.

Possible risks or discomforts you could experience during this study include loss of confidentiality. Every effort will be made to keep your information confidential, however, this cannot be guaranteed. No identifiable information will be collected. All paper files will be destroyed and once the research is complete the data set will be deleted. If results of this research study are reported in journals or at scientific meetings, the people who participated in this study will not be named or identified.

The Office of Human Research of George Washington University, at telephone number (202) 994-2715, can provide further information about your rights as a research participant. Further information regarding this study may be obtained by contacting Marco Segura (Student Investigator / Research Coordinator), at telephone number (###) ### - ####.

*Please keep a copy of this document in case you want to read it again.

APPENDIX C

List of countries/cities identified during data collection

CITY	COUNTRY	LATITUDE	LONGITUDE	TIME ZONE
Asuncion	Paraguay	-25.2667	57.6667	-4.00
Austin, TX	United States	30.2669	97.7428	-6.00
Bangkok	Thailand	13.7500	-100.4833	7.00
Barcelona	Spain	41.3857	-2.1699	1.00
Belize city	Belize	17.4964	88.1828	-6.00
Berlin	Germany	52.5233	-13.4127	1.00
Berne	Switzerland	46.9500	-7.4458	1.00
Bogota	Colombia	4.5981	74.0758	-5.00
Brasilia	Brazil	-15.7810	47.9196	-3.00
Buenos Aires	Argentina	-34.6036	58.3817	-3.00
Canutillo, TX	United States	31.9114	106.5997	-7.00
Caracas	Venezuela	10.5000	66.8992	-4.50
Chantilly, VA	United States	38.8942	77.4314	-5.00
Charleston, SC	United States	32.7764	79.9311	-5.00

CITY	COUNTRY	LATITUDE	LONGITUDE	TIME ZONE
Chennai	India	13.0810	-80.2740	5.50
Chicago, IL	United States	41.8500	87.6500	-6.00
Christ Church	Barbados	13.0833	59.5333	-4.00
Columbia, MD	United States	39.2403	76.8397	-5.00
El Paso, TX	United States	31.7586	106.4864	-7.00
Georgetown	Guyana	6.8000	58.1667	-4.00
Guatemala	Guatemala	14.7162	90.6185	-6.00
Gurgaon	India	28.4700	-77.0300	5.50
Kiev	Ukraine	50.4500	-30.5233	2.00
Kingston	Jamaica	17.9911	76.8036	-5.00
La Paz	Bolivia	-16.4942	68.1475	-4.00
Lima	Peru	-12.0433	77.0283	-5.00
London	England	51.5171	0.1062	0.00
Los Angeles, CA	United States	34.0522	118.2428	-8.00

CITY	COUNTRY	LATITUDE	LONGITUDE	TIME ZONE
Managua	Nicaragua	12.1464	86.2706	-6.00
Mexico	Mexico	19.1300	99.4000	-6.00
Minneapolis, MN	United States	44.9800	93.2636	-6.00
Montevideo	Uruguay	-34.8667	56.1667	-3.00
Nassau	Bahamas	25.0667	77.3333	-5.00
Newark, NJ	United States	40.7356	74.1728	-5.00
New York, NY	United States	40.7142	74.0064	-5.00
Oak Park, IL	United States	41.8850	87.7844	-6.00
Oslo	Norway	59.9494	-10.7564	1.00
Panama City	Panama	9.0000	79.5000	-5.00
Paramaribo	Suriname	5.8667	55.1667	-3.00
Plovdiv	Bulgaria	42.1500	-24.7500	2.00
Port of Spain	Trinidad and Tobago	10.6500	61.4667	-4.00
Port-au- Prince	Haiti	18.5425	72.3386	-5.00

CITY	COUNTRY	LATITUDE	LONGITUDE	TIME ZONE
Prague	Czech Republic	50.0833	-14.4167	2.00
Queretaro	Mexico	20.8378	99.8514	-6.00
Quito	Ecuador	-0.2186	78.5097	-5.00
Reston, VA	United States	38.9686	77.3414	-5.00
Reykjavik	Iceland	64.1333	21.9333	0.00
Rome	Italy	41.9000	-12.5000	1.00
San Antonio, TX	United States	29.4239	98.4933	-6.00
San Jose	Costa Rica	9.9247	84.0781	-6.00
San Salvador	El Salvador	13.6833	89.1833	-6.00
Santiago	Chile	-33.4500	70.6667	-4.00
Santo Domingo	Dominican Republic	18.9473	70.4811	-4.00
South Norwalk, CT	United States	41.0936	73.4186	-5.00
Tegucigalpa	Honduras	14.0942	87.2067	-6.00
Toronto	Canada	43.6481	79.4042	-5.00

CITY	COUNTRY	LATITUDE	LONGITUDE	TIME ZONE
Washington DC, USA	United States	38.8900	77.0300	-5.00