Dispersion, Coordination and Performance in Global Software Teams: A Systematic Review

Nguyen Duc Anh
Department of Computer and Information Science (IDI), NTNU
NO-7491 Trondheim, Norway
anhn@idi.ntnu.no

Daniela S. Cruzes
Department of Computer and Information Science (IDI), NTNU
NO-7491 Trondheim, Norway
dcruzes@idi.ntnu.no

Reidar Conradi
Department of Computer and Information Science (IDI), NTNU
NO-7491 Trondheim, Norway
Reidar.Conradi@idi.ntnu.no

ABSTRACT
Effective team coordination is crucial for successful global software projects. Although considerable research effort has been made in this area, no agreement has been reached on the influence of dispersion on team coordination and performance. The objective of this paper is to summarize the evidence on the relationship among context dispersion, team coordination and performance in global software projects. We have performed a Systematic literature review (SLR) to collect relevant studies and a thematic analysis to synthesize the extracted data. We found 28 primary studies reporting the impact of five dispersion dimensions on team performance. Previously, only two primary studies considered and distinguished all of these dispersion dimensions in studying dispersed team performance. The dispersion dimensions affect team outcomes indirectly through influencing organic and mechanistic coordination processes. Empirical evidence show that geographical dispersion impacts negatively and temporal dispersion has a mixed effect on team performance. While studies with teams working across different time zones shows a tendency that the team performance is pessimistically perceived, studies that use direct measure on task performance shows a positive association to temporal dispersion. The paper provides implications for future research and practitioners in establishing effective distributed team coordination.

Categories and Subject Descriptors
D.2.9 [**Software Engineering**]: Management

Keywords
Systematic literature review, global software development, distribution, team coordination, communication, performance

1. INTRODUCTION
Global software development (GSD) has become a modern paradigm for developing and maintaining software intensive systems. On one hand, organizations are continually spreading and dispersing geographically to seek for mobility in resource, shortening time-to-market, technology innovation, increasing operational efficiency and reducing the negative effect of distance to customers [1]. An ACM report shows that 30% of US IT jobs are expected to be offshored by 2015 [2]. Open source software (OSS) have become popular with more than 160.000 projects registered in Source Forge[1] in the end of 2011, which doubled compared with that in the end of 2004. These figures illustrate for a wide and growing adoption of global development models in software intensive organizations and communities.

On the other hand, globalization is also accompanied by challenges of managing dispersed project activities. Many specialists and managers find global software projects too complex and time consuming to handle. There are an increasing number of problem reports caused by various dispersion dimensions, resulting in a high failure rate of GSD projects [3]. The common mentioned problems of dispersed projects are inadequate communication, different mental models, feedback delays, misunderstanding and lack of trust [4-7]. The claimed benefits of being dispersed and reported obstacles in managing global teams raise a question of cost benefit analysis when dispersing project teams and activities. Understanding the influence of dispersion on project outcomes is crucial to support decisions making on adopting a "going-global" strategy in new projects and improving performance of ongoing projects.

Global team is a concept with multi meanings, which at least consists of offshore team, outsourcing team, virtual team and open source community. Global teams operate in various types of dispersed environments where communication between team members is normally electronic, often asynchronous, with limited opportunities for informal and face-to-face contact [8]. Global teams can be dispersed in different branches of an organization (offshore insourcing), different organizations (outsourcing and partnership) and team members can jointly work in a virtual environment via common online infrastructures (open source and virtual team). In organization research, coordination is defined as an additional activity to manage different type of interdependencies between work tasks and task carriers [9, 10]. Team coordination occurs among project team members in a specific organizational context and follows a specific process to collectively perform the task. As software development activities are intensively interactive and normally complex, the ability to communicate ideas and manage task dependencies is determinant for the team performance, in term of development speed and task accuracy [11]. When software development tasks become larger and dispersed, the interdependencies among the tasks and task carriers become more complicated. This makes coordination in distributed team more difficult and more important than it in collocated team.

Given the significance as well as challenges of team coordination in dispersed context, a growing body of empirical research devotes to comprehend the relationship among dispersion, team coordination and project performance. Synthesis of these studies

ESEM'12, September 19–20, 2012, Lund, Sweden.

[1]http://sourceforge.net

could provide a systematic view of commonalities and variations among primary studies, as well as new interpretive explanations that go beyond the scope of any primary study [12]. In this paper, we present the results of a systematic review of empirical studies of dispersion dimensions and team performance through the lens of team coordination. The main outputs of this SLR are (1) a list of dispersion dimensions and coordination aspects related to team performance, (2) a thematic map that characterizes state of the art on the influence of dispersion dimensions on team performance, (3) and an analysis of a set of context variables that may explain the heterogeneity in the influence directions.

The paper is organized as follows: section 2 presents related literature reviews. Section 3 describes our research methods while Section 4 presents our results and analysis. Section 5 describes our limitations. Section 6 discusses the findings and also conclusions of this paper.

2. PREVIOUS LITERATURE REVIEWS

Prior to this work, some authors have performed literature reviews on different topics in the context of GSD. Among them, there are three SLRs most relevant to our work [13, 14, 15]. Table 1 shows the differences between these works and our study in term of review's focus, scope, method and forms of final results.

Šmite et al. summarized the empirical evidence about the state of the art studies on GSD and discussed on the strength of evidence [13]. The review analyzed context setting of primary studies, such as number of sites, site locations, project life cycle, reasons for starting global collaboration and provided a list of good collaboration practices. Concerning team collaboration, the authors concluded that geographical, temporal and cultural dispersion have a significant effect on how dispersed team communication, coordination and control are done. However, they do not provide details about the effect direction and its influencing factors. In our study, we explored the impact of dispersion on team performance while considering the mediate effect of coordination mechanisms and contextual factors.

Steinmacher et al. reviewed studies about awareness support in GSD projects and its impact on team communication, coordination, and cooperation [14]. While Steinmacher explored antecedent factors that affect team collaboration, our study focuses on team collaboration as a mediator of the relationship between dispersion and team performance. Additionally, Steinmacher included both empirical, theoretical and tool review papers, while our review only focuses on empirical evidence.

Table 1: Related literature reviews

Study	#	Focus	Main Final Product
Šmite et al. 2010 [14]	59	Project type, research topic, reasons for starting global collaboration and good practices for GSD	List of best practices Descriptive statistic of study features
Steinmacher et al. 2010 [15]	42	Support of awareness on communication, coordination and cooperation in GSD	List of awareness aspect
Noll et al. 2011 [16]	26	Barriers and solutions for collaborating in GSD	List of barriers and solutions
This study	28	Relationship among dispersion, coordination and team performance in GSD	Thematic map List of influencing context factors

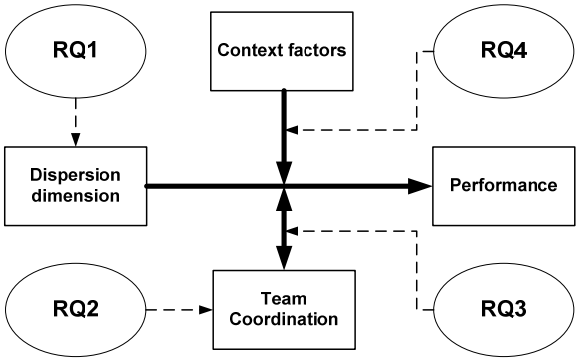

Figure 1: Research questions

Noll et al. reviewed studies about challenges and solutions for collaboration in software development teams [15]. The authors described key barriers to collaboration, such as geographic, temporal, cultural, and linguistic dispersion; and also solutions to overcome these barriers, such as site visits, synchronous communication technology, and knowledge sharing infrastructure. While this study performs a narrative summary of collaboration in distributed context, we thematically synthesize the direction of dispersion's influence on team performance and details of the influences through the lens of team coordination processes.

3. METHODOLOGICAL APPROACH

The main goal of this study is to summarize empirical evidences on the impact of dispersion on team performance mediated by team coordination. We planned, conducted, and reported the review results by following the SLR process suggested by Kitchenham [16].

3.1 Research Questions

The review objective is divided into four research questions as shown in Figure 1. We adopted the common input-process-outcome model to organize research questions and to provide the basics for integrating literatures [17]. The input part represents the starting conditions for teamwork, such as dispersion context of the projects. Although GSD is frequently mentioned in Software Engineering (SE) literature, it is not clear which dispersion aspects or dimensions are actually investigated and measured (RQ1). The process part represents the dynamic interaction among team members such as team coordination processes. The dispersion context of projects should have some influences on team coordination before it results in teamwork outcomes (RQ2). The outcome part represents team performance as consequences of a team's functioning in a specific context. Given concepts addressed in RQ1 and RQ2 as the basis, we investigated the relationship between dispersion, team performance and the mediate role of team coordination (RQ3). We also expected heterogeneous findings on the influences of dispersion dimensions on project performance among primary studies. Therefore, RQ4 searches for some possible explanations by investigating the study contextual factors. In short, the research questions investigated in this systematic review are:

RQ1: Which dimensions of dispersion are explored in relationship between the dispersion and team performance?
RQ2: How is team coordination investigated and influenced by the dispersion dimensions?
RQ3: How does the dispersion dimensions influence the teams' performance?
RQ4: Which contextual factors could explain the heterogeneity among empirical findings on the influence directions?

3.2 Search and Selection Strategy

The review process consisted of six phases, as shown in Figure 2. At first, we conducted an ad-hoc literature review on team coordination in global software projects. The goal was to understand the conceptual background and emergent issues for further investigation. A list of initial studies was identified to formulate the search string and to perform a validity check for the systematic search later. In the second step, we developed a review protocol, which specifies search terms, databases, search inclusion and exclusion criteria, quality assessment and a data extraction form. We conducted a pilot search and data extraction to test and refine the review protocol. The search terms were adjusted based on the search coverage and accuracy [18]. Besides, the data extraction form was also adjusted based on the extracted information from sample studies.

After refining the review protocol, the systematic search was carried out with a similar procedure of the pilot search. The search results were validated by its coverage of the initial papers. A screening process was performed to identify eligible studies (title and abstract, followed by full text review). After that, the quality of studies was assessed and studies with lowest quality scores were removed. In order not to miss any important papers, we performed an additional search by scanning the reference list forward and backward.

The search string consists of 3 parts: *(Coordination Or synonyms) AND (Dispersion Or synonyms) AND context.* The synonyms were identified in the context of SE and Information System (IS). As the ad-hoc review revealed that there is no distinguished use of terms "coordination", "collaboration" and "cooperation" in SE and IS literature, we considered them as interchangeable concepts. Several trial searches were conducted to determine which search string was most appropriate. The search was performed in two literature databases, namely Scopus and ISI. As common search fields in SLR, we searched in papers title, keyword and abstract with no restriction of the period of time. The final search string is:

(coordinati or collaborativ* or cooperati*) AND (distributed or offshor* or "open source" or outsourc* or global or dispers*) AND (software or project or team) IN (Title or Abstract or Keyword)*

The selection process resulted in 28 papers studying impact of dispersion on team performance (See full list in Appendix). We included papers that: (1) investigate concepts, problems and solutions of coordination in GSD context; (2) and apply at least one of empirical methods to answer the proposed research questions.

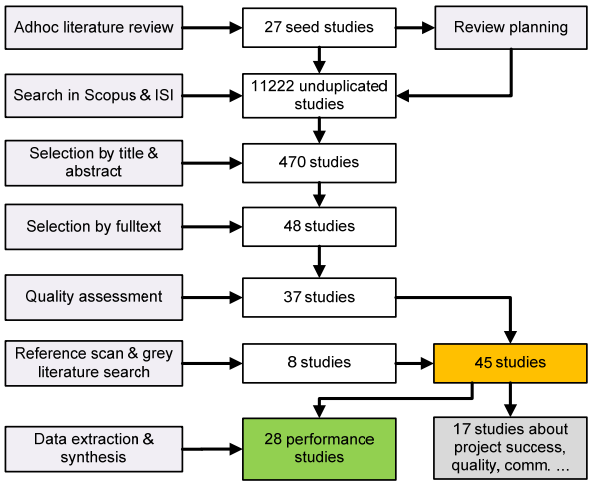

Figure 2: Search strategy and result

Table 2: Quality assessment checklist

Problem statement
1. Is the aim of the research sufficiently explained and well motivated?
Research design
2. Is the context of study clearly stated?
3. Is the research design sufficiently prepared beforehand?
Data collection
4. Are the data collection and measures adequately described?
5. Are the measures used in the study relevant for answering the research question?
Data analysis
6. Is the data analysis used in the study adequately described?
7a. Qualitative study: Are the interpretation of result clearly described?
7b. Quantitative study: Are the effect size reported with assessed statistical significance?
8. Are potential confounders adequately controlled or discussed?
Conclusion
9. Are the findings of study clearly stated and supported by the results?
10. Does the paper discuss limitations or validity?

We excluded 56 short papers (less than 6 pages) that do not provide sufficient information about data collection, analysis methods and interpretation of findings. We also excluded studies that either: (1) are not in SE or IS area; (2) are not about dispersed context; (3) investigate coordination-supported infrastructures or tools such as wiki-based systems and social network platforms; (4) do not have empirical validation; (5) or only focus on team coordination without relationships with project outcomes.

We devised a number of quality assessment questions to assess the rigorousness, credibility, and relevance of the relevant studies from Dybå and Dingsøyr's checklist [19]. The list of questions is shown in Table 2. Each question has three possible options: "Yes" (score 1), "Partially" (score 0.5) and "No" (score 0). For a given study, the quality score was counted by summing up the scores ofall questions. To ensure the reliability of the findings of this review, we considered only the studies with quality score equal or greater than 5. We classified papers with score 5-6 as weak, 7-8 as medium and 9-10 as strong quality.

3.3 Data Extraction

The following information was extracted from selected studies: research design (research question, research design type, case study type, unit of analysis, sample size, data collection method, data analysis method, threats to validity); context setting (project description, number of site, site location, level of technology support), dispersion factor (name, explanation, measure), coordination aspect (name, explanation and measure), project outcome factors (name, explanation, measure), findings and implications. We distinguished studies that investigate multiple data sources in a period of time (case study) with studies that explore project repository without sufficient context description (data archive). We also distinguished between a study and a paper since a paper could report more than one study. Table 3 describes some characteristics of the 28 papers included in the SLR. Some studies adopt more than one research method and measurement approach.

Regarding to study design, survey is the dominant type with 46% of the studies, followed by data archive (32%) and case study (28%). Considering project type, 68% of the studies are about coordination in inner context, or offshore team within an organization. Five studies investigate outsourcing context and four studies explore coordination in OSS projects. Twenty three studies focus on developers level while 14 studies consider manager's viewpoints.

Table 3: Primary study characteristics

	P01	P02	P03	P04	P05	P06	P07	P08	P09	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25	P26	P27	P28	Total	%
Study design (Section 3.3, 4.4)																														
Survey	◆	◆		◆						◆		◆	◆		◆			◆		◆		◆	◆			◆	◆		13	46%
Data archive	◆						◆	◆			◆			◆		◆			◆		◆			◆					9	32%
Case study	◆	◆	◆		◆												◆											◆	6	21%
Interview									◆			◆						◆											3	10%
Experiment						◆																			◆				2	7%
Data analysis (Section 4.4)																														
Quantitative	◆	◆	◆	◆		◆	◆	◆		◆	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	25	89%
Qualitative					◆				◆								◆							◆					4	14%
Global type (Section 4.4)																														
Inner	◆	◆	◆		◆	◆	◆		◆	◆	◆	◆	◆	◆				◆	◆	◆		◆		◆	◆		◆		19	68%
Outsource				◆											◆		◆									◆		◆	5	18%
Open source								◆								◆					◆		◆						4	14%
Subject (Section 4.4)																														
Developer	◆	◆	◆		◆		◆	◆			◆	◆	◆	◆	◆	◆	◆	◆	◆		◆	◆	◆	◆	◆	◆	◆	◆	23	82%
Manager	◆			◆	◆				◆	◆		◆	◆		◆		◆	◆		◆		◆				◆	◆		14	50%
Student						◆																							1	4%
Quality (Section 3.3)																														
Strong		◆	◆	◆	◆		◆	◆	◆			◆	◆		◆		◆	◆	◆	◆	◆		◆			◆	◆	◆	19	68%
Medium						◆								◆															2	7%
Weak	◆									◆	◆					◆						◆		◆	◆				7	25%
Dispersion (Section 4.1, Section 4.3)																														
Geographical	◆	◆	◆				◆		◆		◆	◆	◆	◆			◆	◆	◆	◆				◆	◆		◆		16	57%
Temporal			◆	◆		◆		◆	◆				◆							◆						◆		8	28%
Organizational				◆	◆				◆				◆		◆						◆	◆			◆			8	28%
Work process			◆				◆		◆				◆				◆						◆					◆	7	25%
Cultural				◆					◆	◆			◆		◆														5	18%
Coordination (Section 4.2)																														
Organic	◆	◆			◆		◆		◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆		23	82%
Mechanistic				◆	◆	◆		◆	◆			◆					◆	◆							◆	◆		◆	11	39%

4. RESULTS

Thematic synthesis was used for synthesizing the results, following the recommended steps proposed by Cruzes and Dybå [20]. Firstly we identified the emerged dispersion dimensions from the papers. Secondly, we summarized empirical findings about their influence on team coordination on a thematic map. Lastly, we captured emergent themes that provide the guidance for comprehending the thematic map.

4.1 RQ1: Dimensions of Dispersion

There are five dimensions of dispersion emerging from the literature, namely: geographical, temporal, cultural, work process and organizational dispersion.

Geographical dispersion, which is also denoted as spatial distribution or physical proximity, is the most frequently investigated dimension of dispersion (57% of the papers). Geographical dispersion is commonly defined as the geographical difference in working places among project stakeholders. The metrics applied for this type of dispersion vary among primary studies. Most studies measure geographical dispersion by a dichotomous variable to differentiate team processes and outcomes between collocated and distributed teams (P1, P2, P7, P14, P18 and P19). Three studies consider degree of dispersions, e.g. number of sites (P3, P11 and P25) and three studies consider whether team member was located in the same room or different building, city, or country (P13, P20 and P27). Geographical dispersion introduces issues of using collaboration technology to alternate the face-to-face and synchronous communication (P20, P24 and P27).

Temporal dispersion is investigated in 28% of the papers. It occurs when a project' works are separated through different working hours, time zones, and work shift. The temporal dispersion introduces the issue of time synchronization when working time differences should be aligned with workflows (i.e. work is handed over at the end of the work day to a site whose work day is just beginning). Most of the studies measure temporal dispersion by the (degree of) difference in time zone among project team member (P3, P4, P6, P9, P13, P20 and P27). Temporal dispersion also accounts for situations where team members are located at the same site but in different shifts or even flexible hours (P8). In the open source context, P8 quantifies the temporal dispersion as a variance in developer's starting time.

Organizational dispersion occurs when the project work is shared across organizational boundaries, such as in a vendor-client relationship and ecosystem partnership (P4, P5, P15, P22 and P26). Organizational boundary also occurs between functionally independent units of the same organization (P9, P13). Organizational dispersion is investigated in 28% of the papers. This type of dispersion introduces issues of contractual obligations, cooperation and competition, goal conflicts, knowledge integration, different work process, different kind of coordination strategy and mechanism (P4, P9, P22 and P26). Organizational dispersion suffers from a relatively high level of conceptual ambiguity and was mainly qualitatively explored in these studies. Only one study uses boundary spanning subject, process and object as the quantitative measure for organizational dispersion (P26).

Work process dispersion (25% of the papers) refers to the difference in functional and process aspects of dispersed tasks (P9, P13, P17 and P28). Stakeholders in different working places can have different working environments, independently of being in the same time zone and the same organization. They may adopt different communicating and collaborating processes and may have

different level of work infrastructure, such as computer, network, configuration, communication and development tools (P9, P13 P17 and P28). Besides, different sites can take charge of different project phase activities, such as one team for requirement analyst and the other team for development (P17, P28).

Cultural dispersion (18% of the papers) is normally mentioned as the difference in stakeholders' cultural background, such as language, mental model and subtle cognition (P9 and P13). Project stakeholders from different countries often have different perspectives on issues and different ways of communicating and resolving them (P4 and P10). For example, Western hierarchical relationships are more influenced by contractual agreements and an ideology of essential, while Indian hierarchical relationships are more oriented towards mutual obligations and emotional relationship (P4). In P10, cultural dimension is measured by power distance, individualism, masculinity, uncertainty avoidance, and long-term orientation. All the studies on cultural dispersion focus on the cultural differences in the nations or continents level, and no study explore the cultural differences in lower levels, such as regions and organizations.

It is noticed that in primary studies, these dispersion dimensions are overlap concepts and insufficiently explored in literature. While temporal and cultural dispersion could be embedded in the geographical dispersion, an organizational dispersion normally introduces work process dispersion. O'Leary and Cumming suggested a set of variables to quantify spatial-temporal and organizational distance [21].

4.2 RQ2: Coordination Mechanism

In social science, Thompson labeled two types of organizational structure, namely organic and mechanistic organization [22]. Organic organizations rely on lateral communication to exchange information rather than vertical communication to give direction. The coordination is based upon expertise and knowledge rather than on authority of position. Mechanistic organizations are characterized by high complexity, formalization and centralization. The organizations perform routine tasks and rely heavily on programmed behaviors. Based on Thompson's model, we organized the coordination aspects that are influenced by team coordination into two categories, namely organic coordination (82% of the papers) and mechanistic coordination (39% of the papers).

4.2.1 Organic Coordination

Organic coordination, or mutual adjustment, or social coordination mechanism, is the use of lateral communication means to coordinate activities [22]. Grounded from primary studies, organic coordination is influenced by dispersion dimensions via the frequency of communication and feedback, coordination delays and misinterpretation.

Frequency of communication and feedback: distributed team communication is much less frequently studied than collocated team communication (P2). Temporal dispersion limits the ability to communicate synchronously (P9) also creates difficulties in asynchronous communication (P20). However, the negative impact of distance on communication frequency is significant in early phases of projects and decreases somewhat over time (P2 and P5).

Coordination delay: time zone differences create discontinuity in dispersed tasks, which leads to a delay in asynchronous communication (P20, P27). Organizational differences introduce problems of complex escalation and delay in communication. Distributed communication differs from collocated communication in a way that it requires more people to participate, thereby introducing delays (P2). As a surprising finding, P11 showed that distributed communication does not appear to introduce a significant amount of delay compared to collocated task completion time. In the study, modern shared workspace and task-driven communication is thought to account for mitigating coordination delay.

Misinterpretation: lacking of face-to-face contact, differences in working time and cultural background could make people misinterpret other's behaviors (P4, P9, P13). Differences in communicating language also cause remote members to switch to their native language. This leads to a mismatch in conversation style, and consequently difficulties in technical collaboration (P4, P15).

4.2.2 Mechanistic Coordination

Mechanistic coordination is the use of vertical communication means to coordinate activities in a programmed way, such as direct supervision and standardization, task organization, role assignment, schedules, plans, division of labor, project controls and specifications, routine meeting and status check (P6, P9, P17, P18, P26 and P28). Mechanistic coordination in distributed team is influenced by dispersion dimensions via team coordination structure, task scheduling complexity and coordination requirement gaps.

Team coordination structure: geographical and temporal dispersion introduce problems in organizing effective communication structure. Hierarchical structure of communication networks introduces the role of brokers who are in the connection with many other developers (P5). They are more likely to sustain collective actions, tend to reduce coordination gaps and increase coordination effectiveness. However, this centralization pattern also introduces a bottleneck since relying on a broker makes the entire issue tracking efficiency dependent on his (her) availability (P24). Democratic communication structure where team member freely communicate to each other is also problematic since it introduces complex communication paths and overloaded communication content (P12). High degree of network density creates redundant information flows, which may have a negative effect on the coordination performance (P16).

Task scheduling complexity: in the dynamic of task dependency and uncertain collaboration environment, lacking balance in adopting coordination mechanisms not only leads to coordination pitfalls, but also affects the remote team performance (P17). Team spanning through many different time zones are difficult to organize tasks, such as scheduling conference calls and setting up meeting for all relevant sites (P6, P27). Identifying roles and dividing tasks in distributed context, especially withwork process and organization dispersion, is much harder than those in homogeneous environment (P07). However, P8 showed that in the open source project context, time separation does not cause coordination problems but increase the total time available to projects by allowing developers to take the extra time to code appropriately.

Coordination requirement gap: geographical dispersion obstructs the identification of coordination requirements from team dependency. In comparison with collocated team, finding who should talk to whom in a collaboration is more difficult in distributed context (P01, P14, P19). Socio-technical congruence, which is defined as a match between coordination requirements established by task dependencies and the actual coordination activities carried out by developers, is harder to identify in distributed contexts (P19). Geographical distribution introduces more and larger coordination requirement gaps (P01). While knowledge broker would help to partially close the gaps, the remained problem is to align role assignment with informal communication structures and the dynamic nature of coordination requirements (P01, P19).

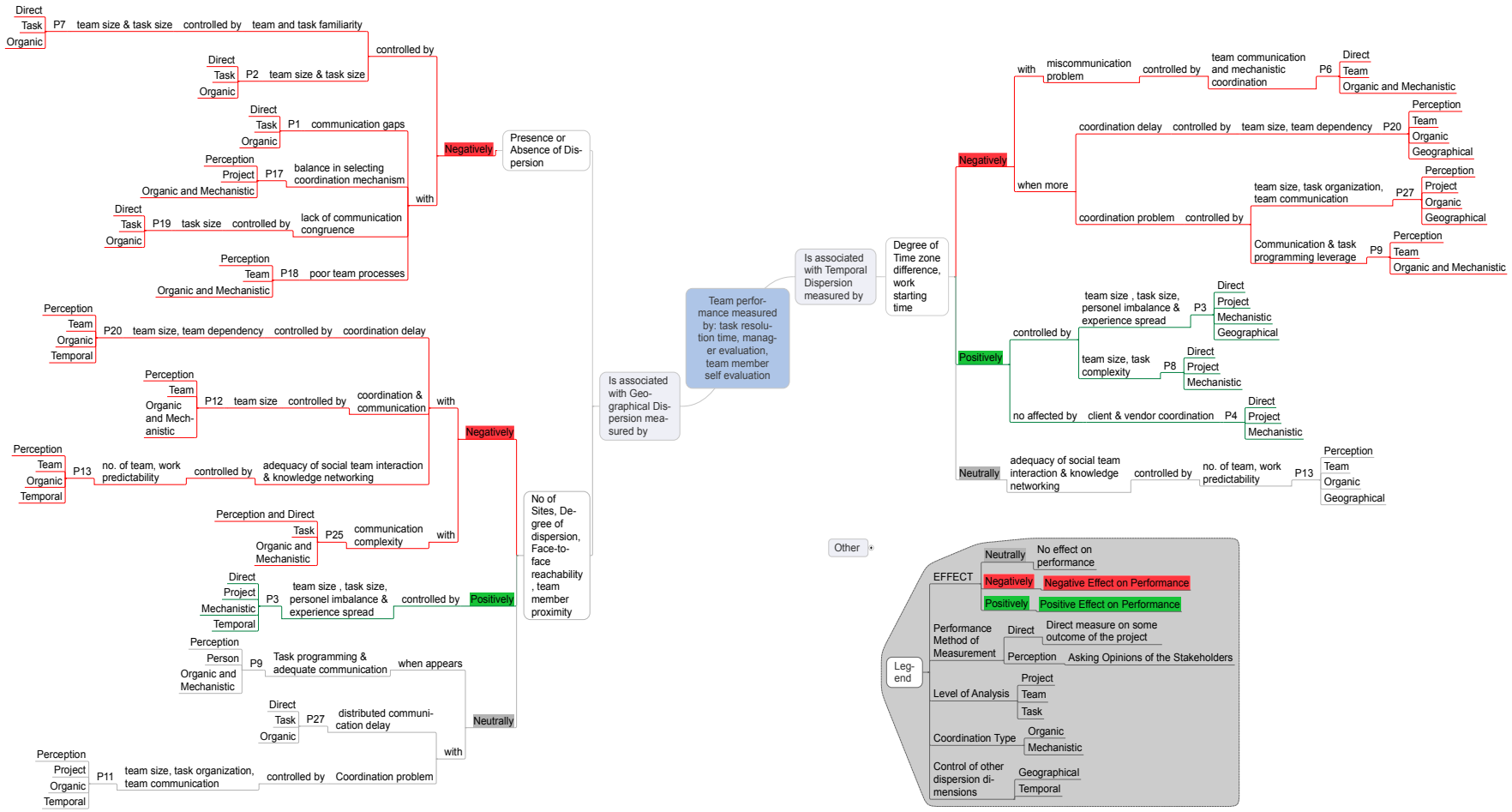

Figure 3: Impact of geographical and temporal dispersion on performance

4.3 RQ3: Dispersion and Team Performance

In this paper, we focused on the two main types of dispersion: geographical and temporal and the influence of them on the team performance. Figure 3 shows the final thematic mind map as a result of the synthesis. The map is read from the root and go down till the leaves as the below order:

> Team performance is associated with [*Dispersion measures*] [*Positively/Negatively/Neutrally*] with [*Coordination aspects*] controlled by [*Context factors*] in [*Study ID*]

In the included papers, team performance is measured in three main ways: (1) evaluation of project managers' on project performance (work on schedule and within budget) (P5, P6, P8, P9, P12, P13, P17, P18 and P20), (2) time to complete a shared task (P2, P7, P11, P14 and P19), (3) and amount of task (P1, P3, P6 and P25). The direction of influence of dispersion dimensions on team performance is decided by the direction of the dispersion variables in a statistical test model (correlation or regression models) from quantitative data or grounded conclusions from qualitative data in primary studies.

In summary, ten studies show a negative influence of geographical dispersion on team performance; one study shows a positive influence and three studies report a neutral effect. Regarding to temporal dispersion, four studies show a negative influence, three studies show a positive impact and one study report a neutral effect. We discuss these results in the following sections.

4.3.1 Presence or Absence of Geographical Dispersion

The presence or absence of the geographical dispersion was the measure of dispersion in six papers (P1, P2, P7, P17, P18 and P19). All of them reported a negative association between geographical dispersion and team performance.

In P2, the authors found that distributed work items take about 2.5 times as long to complete as similar items where all the work is collocated. In P17 and P18, the authors also found that distributed teams are less effective in communication and lower in performance than collocated teams are. The negative effect of geographical dispersion on the team performance is indirect via teamwork processes, such as communication and coordination process (P2, P18, P20 and P27) or requirements gaps (P1). This delay could be introduced by more relevant people than comparable same-site work items (P2), restricted flow of information across sites, lack of face-to-face contact, spontaneous communication, and shared social settings (P13). Consequently, it creates great difficulty in finding people and reducing the likelihood of obtaining useful information from them (P2). Distributed work introduces disparities in working practices, issues of trust among distributed development units, lack of face-to-face contact and constant feedbacks. Lacking balance in selecting coordination mechanisms not only leads to coordination pitfalls, but also affects the remote team performance (P17). The coordination problems are not only to identify interdependence between developers and tasks, but also the dynamic of coordination requirements when this interdependence changes over time (P19).

4.3.2 Degree of Geographical Dispersion

Eight papers (P3, P9, P11, P12, P13, P20, P25 and P27) measure geographic dispersion in terms of number of sites involved or the degree of dispersion. Four papers reported the negative effect (P12, P13, P20 and P25), one positive (P3) and three neutral effect (P9, P11 and P27) of geographical dispersion in team performance as shown in Figure 3.

In P12, P13, P20 and P25, authors found that geographical congruence had a negative effect on performance. Greater work place mobility, such as working in different sites, working from home or while travelling has a negative impact on team performance (P13, P20). An experiment with students showed that the average working speed of each individual site declines about 20 percent when each development site added (P25). Increasing the number of locations also complicates coordination and hampers the communication in the project status and feedback. The increased of number of site complicates coordination and hampers the communication in the project status and feedback (P25). This collaboration problem makes developers avoid conflicts by writing and maintaining code locally. Consequently, integrating or using code developed from other sites is more demanding (P2). In P12, geographical dispersion amplified the impact of teamwork quality on team performance. As the team members are more geographically dispersed, the influence of teamwork quality on team performance increases.

In P9, P11 and P27, authors did not find a significant relationship between the geographical dispersion and the performance. In P9, reducing or eliminating the impact of geographic dispersion was costly; but some participants stated that they had to invest more resources to overcome the difficulties of working over geographic distance. In P27, spatial separation alone was not directly associated with team performance; lower performance was primarily due to coordination problems created by a large time zone span. In P11, the authors concluded that the effect of distance is mitigated in collaborative environments such as Jazz, in which communication in large distributed work teams is facilitated by an ability to asynchronously comment on tracking activity of work items.

In contrary to the above-mentioned papers, P3 shows that when organizations distribute across geographical dispersion, such as increasing number of sites leads to increasing productivity at project level. However, the imbalance in personal experiences among development sites decrease productivity and geographical dispersion was found to have a negative impact on product quality (P3).

4.3.3 Degree of Temporal Dispersion

Eight studies investigated the influences of temporal dispersion on team performance (P3, P4, P6, P8, P9, P13, P20 and P27). Among them, four studies reported a negative effect (P6, P9, P20 and P27), three studies showed a positive effect (P3, P4 and P8) and one study reported an inconclusive result about the influence of temporal dispersion on team performance (P13).

Project managers tend to perceive the impact of temporal dispersion on team performance negatively (P6, P9, P20 and P27). Survey and interview of managers show that difficulties in maintaining awareness of distributed activities and lack of appropriate coordination mechanisms leads to negative effects on project performance in terms of time and budget overruns, lower system quality and customer satisfaction (P9, P20 and P27). The small time separation with some overlapping hours does not create substantial coordination problems, but greater time zone span is associated with more coordination problems, i.e. 9–12 hours span creates severe effects (P27). A complex model of time separation influence is presented in P6, which show that development speed decreased significantly with very small amounts of time separation (i.e., 2/3 overlap). Teams in the 1/3 overlap had lower levels of speed than full overlap, but the difference was less significant than for 2/3 overlap. The authors hypothesize that with more complex and equivocal tasks that require more frequent interaction, speed will be dramatically affected by time separation, but this effect may also be influenced by learning effects (P6).

In P13, temporal dispersion was not found to be significantly associated with team performance, including mutual trust among team members, effectiveness of communication and coordination, commitment and contribution of individual members, and quality and punctuality of team products. The given reason is that adoption of advanced working environment or evolution of communication pattern can offset the influence of dispersion dimensions.

In contrary to results from the above papers, P8 showed that temporal dispersion is positively associated with the speed and the quality of coding, in the context of OSS. Greater temporal dispersion allows project progress to be continually monitored, reflected, and revised around the clock, thereby leads to higher quantity-per-unit and quality of code. Temporal boundary is also found to have a positive effect on development speed in offshored context (P4). The given reason is that the difference in time zones may allow managers to leverage the "24 hour work-day" in making more effective use of calendar time on a project. These duration advantages are greater when the time separation is larger, i.e., India and US versus India and Singapore. In addition, a study of 246 industrial projects at the project level showed that when organizations distribute across spatial and temporal dispersion, they increased project level productivity (P3).

4.4 RQ4: Leveraging Effects of Context Factors

To explain for the differences in the influence directions among these papers, we explored some characteristics of the research methods and contextual factors by a data mining tool called Weka[2]. We applied C4.5 algorithm to build a classification tree of impact direction based on context factors [23]. The explored factors were: research method features such as performance measure type (perception based or direct measure), level of analysis (project, team or work item), sample size (small, medium or large), subject type and quality of study, context setting factors, such as level of technology infrastructure, dispersion range (project spread in 1, 2, or 3 continents) and global development type (inner, outsource or open source). The thematic map also reveals the adequate control level of task and team characteristics, which are basics for investigating team coordination (as shown in Figure 3).

The classification results show that sample size, subject type, dispersion range and global development type is not able to classify the direction impact. Level of communication technology support was disappointed to us since most of these papers were not clear about this factor, so we couldn't discuss the effect of this on the results. The only two factors that provided clusters with an acceptable homogeneity were performance measure and level of analysis. The summary of these two factors is shown in Table 4. Positive, negative or neutral impacts are marked by "(+)", "(-)" or "(O)" respectively.

On the *performance measure*, all of the investigated studies that use perception-based measurement show a negative or neutral impact of geographical and temporal dispersion on performance. Regarding to temporal dispersion only, performance measure type classify direction of the influences. Perception-based studies report a pessimistic view of the impact of dispersion on team performance while studies on direct measurement show positive results. This suggests that the psychological dispersion might not necessarily overlap with the physical dispersion, which confirms the "far-but-close" phenomenon in distributed working environments [24].

[2]http://www.cs.waikato.ac.nz/ml/weka

Table 4: Influencing context factors

Context factors	Geographical			Temporal		
	(+)	(-)	(O)	(+)	(-)	(O)
Total studies	**1**	**11**	**3**	**5**	**3**	**1**
Performance measure						
Perception	0	7	2	0	3	1
Direct measurement	1	4	1	5	0	0
Level of analysis						
Project	1	1	2	3	1	0
Team	0	5	0	2	2	1
Task	0	5	1	0	0	0

Concerning the *level of analysis*, 100% of studies (6 out of 6) that investigate team performance at task level report negative or neutral impacts of geographical dispersion on task resolving performance. 80% of studies (8 out of 10) that investigate team performance at team level show non-positive results. These results are observed in only 50% of studies (4 out of 8) at project level. The decrease of homogeneity of influence direction when increasing granularity level of analysis might indicate that the negative impact of dispersion dimensions is mediated by some team and project level context factors.

5. LIMITATIONS

In the process of selecting and aggregating results from primary studies, we faced various challenges related to quality of studies and heterogeneity of study context.

5.1 Challenges in Synthesizing Findings

Context factors are important to reason about the influence of dispersion dimensions on team coordination and performance. However, only few studies sufficiently and properly reported the context setting. Details about geographical and organizational context, such as site locations, involved parties and collaborative work processes are important to identify and isolate the influences of each dispersion dimensions. However, this information is often missing in literature. Besides, to understand the level of coordination practices, communication process and technology should be described as well. While availability of collaboration technology and its adoption level could be a mediate factor of team dispersion on performance, most of the primary studies do not give enough information about it.

Another challenge is to integrate results from quantitative studies and qualitative studies. The heterogeneity of primary studies does not allow quantitative summary methods, such as meta-analysis on the whole set of studies. Therefore, a qualitative thematic synthesis and a clustering analysis on temporal and geographical studies were selected. Besides, the variety of unit of analysis, measurement of dispersion and team performance make us difficult to interpret and generalize the findings to a larger extent.

5.2 Threats to Validity

Even though we have conducted a thorough process of searching and selecting primary studies, we are aware that the selection process may not captured all of the relevant studies, especially ones that have not been indexed in Scopus or ISI.

Another threat to SLR type of study is reviewer's bias in study selection and synthesis [16]. To reduce this threat, the selection process was conducted by the two first authors and constantly crosschecked. These two authors also jointly performed the synthesis. Conflicts were discussed until consensus was reached. Additionally, the third reviewer checked the paper selection and result of analysis from an outsider's perspective.

A threat to external validity of this SLR is generalization. The limited number of studies on each dispersion dimension (16 studies at most) does not allow us to conduct formal statistical analysis. However, consensus observations from these studies suggest important context factors that should be further investigated.

As mentioned in the challenges, we were limited to the context factors that are commonly reported in the studies. Therefore, it might be that the direction of dispersion's influence on team performance is explained by other factors, which is less visible from these studies.

6. CONCLUSIONS

This study identified five common dispersion dimensions in empirical studies about global software development team performance. These dispersion dimensions are often not clearly distinguished and comprehensively studied in the literature. While temporal, geographical and organizational dispersion are the most investigated types of dispersion, the amount of empirical studies that focus on work process and cultural dispersion are relatively small and mainly qualitative in research methods.

The synthesized evidence shows that dispersion dimensions do not directly impact team performance but indirectly via team coordination problems. The dispersion dimensions reduce communication frequency, created coordination delays and misinterpretation in lateral communication. They also introduce problems of team organizing, task scheduling and managing task-team interdependency in vertical coordination.

The analysis of studies on geographical and temporal dispersion shows that overall geographical dispersion has a negative impact on performance of distributed teams, in both subjective and objective measurement. The impact of temporal dispersion on team performance is negatively perceived by managers, while this impact is positive by direct measure at task level. Besides, studies at task level report more homogeneously negative impact of dispersion dimensions than studies at team and project level do.

The implications of this review for research are threefold. Firstly, inconclusive impacts of temporal and geographical dispersion on performance call for more research efforts on this topic. Future studies on GSD should take into account all type of dispersion dimensions to have a complete description of the context. Secondly, the review reveals a relatively small amount of study on open source context. As open source paradigm is getting more success as a distributed development model, coordination practices in OSS projects could provide useful lessons for commercial software projects. Future research should explore more on team performance in considering dispersion dimensions and the role of open source communication infrastructure on this relationship. Finally, the review discloses a significant amount of studies on geographical, temporal and organizational dispersions, while not so many studies have really focused on two other dispersion dimensions. This suggests an opportunity for future research on the relationship between cultural and work process dispersion on team performance.

The implications of this review for practice are also threefold. Firstly, since mechanistic coordination is as important as organic coordination in mediating and improving project performance, management level should not only build an informal communication community around the projects, but also construct an effective formal coordination mechanism and strategy. Secondly, project managers tend to have a pessimistic view on being distributed over physical spaces and time zones. Therefore, managers should look for more objective evidences on the impact measurement for a comprehensive view of cost-benefit when involving in global software projects. Finally, given significant role of team coordination in achieving project success, manager should invest on team configuration early in the project as a basis for facilitating coordination in later phases.

This review reports aggregated findings on the set of studies about team performance and mainly focus on geographical and temporal dispersion. Future extension of this work would explore the other three dispersion dimensions as well as synthesize the evidenceson the influence of these dispersion dimensions on product quality, coordination effectiveness and team performance.

7. ACKNOWLEDGEMENT

We gratefully appreciate Professor James D. Herbsleb from the Institute for Software Research, CMU for valuable discussions on the systematic review.

8. REFERENCES

[1] J. D. Herbsleb, D. Moitra, "Guest Editors' Introduction: Global Software Development", *IEEE Software,* vol. 18, pp. 16-20, 2001

[2] ACM Job Migration Task Force, " Globalization and Offshoring of Software", *Association for Computing Machinery,* 2006

[3] M. Fabriek, M. Brand, S. Brinkkemper, F. Harmsen, and R. W. Helms, "Reasons for success and failure in offshore software development projects", European Conference on Information Systems, pp. 446-457, Galway, Ireland, 2008

[4] D. Damian and D. Moitra, "Guest Editors' Introduction: Global Software Development: How Far Have We Come?", *IEEE Software*, vol. 23, no. 5, pp. 17– 19, 2006

[5] N. B. Moe and D. Šmite, "Understanding a lack of trust in Global Software Teams: a multiple-case study", *Software Process: Improvement and Practice*, vol. 13(3), pp. 217–231, 2008

[6] D. Šmite, N. B. Moe, and R. Torkar, "Pitfalls in remote team coordination: Lessons learned from a case study", *LNCS*, vol. 5089, pp. 345-359, 2008

[7] J. A. Espinosa, J. N. Cummings, and C. Pickering, "Time Separation, Coordination, and Performance in Technical Teams", *IEEE Trans. on Engineering Management*, vol. 59, pp 91-103, 2011

[8] J. Lipnack and J. Stamps. *Virtual Teams, Reaching Across Space, Time and Organizations with Technology*, John Wiley & Sons, 1997

[9] B. Curtis, "Modeling coordination from field experiments", Conference on Organizational Computing, Coordination and Collaboration: Theories and Technologies for Computer-Supported Work, Texas, USA, 1989

[10] T. W. Malone and K. Crowston, "What is coordination theory and how can it help design cooperative work systems?", Conference on Computer-supported cooperative work, pp. 357-370, California, United States, 1990

[11] R. E. Kraut and L. A. Streeter, "Coordination in software development," *Communication of ACM*, vol. 38(3), pp. 69–81, 1995

[12] D. Cruzes and T. Dybå, "Research synthesis in software engineering: A tertiary study", *Information & Software Technology*, vol. 53(5), pp. 440-455, 2011

[13] D. Šmite, C. Wohlin, T. Gorschek, and R. Feldt, "Empirical evidence in global software engineering: a systematic review," *Empirical Software Engineering*, vol. 15(1), pp. 91–118, 2010

[14] I. Steinmacher, A. P. Chaves, and M. A. Gerosa, "Awareness support in global software development: a systematic review based on the 3C collaboration model", 16th Conference on Collaboration and Technology, pp.185–201, Maastricht, The Netherlands, 2010

[15] J. Noll, S. Beecham, and I. Richardson, “Global software development and collaboration: barriers and solutions,” *ACM Inroads*, vol. 1(3), pp. 66–78, 2011

[16] B. A. Kitchenham, “Guidelines for performing Systematic Literature Reviews in Software Engineering”, EBSE Technical Report, 2007

[17] J. R. Hackman and C. G. Morris, “Group Tasks, Group Interaction Process, and Group Performance Effectiveness: A Review and Proposed Integration”, *Advances in Experimental Social Psychology*, vol 8, pp. 45-99, Academic Press, 1975

[18] O. Dieste and A. G. Padua, “Developing Search Strategies for Detecting Relevant Experiments for Systematic Reviews”, pp. 215–224, ESEM, Madrid, Spain, 2007

[19] T. Dybå and T. Dingsøyr, “Empirical studies of agile software development: A systematic review”, *Information and Software Technology*, vol 50, pp. 833-859, 2008

[20] D. S. Cruzes and T. Dybå, “Recommended Steps for Thematic Synthesis in Software Engineering”, pp. 275–284, ESEM, Calgary, Canada, 2011

[21] M. B. O’ Leary, and J. N. Cummings, “The spatial, temporal, and configurational characteristics of geographic dispersion in teams”, *MIS Quarterly*, vol. 31(3), pp. 433-452, 2007

[22] J. Thompson, *Organizations in Action*, McGraw-Hill, 1967

[23] J. R. Quinlan, *C4.5: Programs for Machine Learning*, Morgan Kaufmann Publishers, 1993

[24] J. M. Wilson, M. B. O’ Leary, A. Metiu and Q. R. Jett, “Perceived proximity in virtual work: Explaining the paradox of far-but-close”, *Organization Studies*, vol. 29(7), pp. 979-1002, 2008

Appendix - Studies Included in The Review

[P1] K. Ehrlich, M. Helander, G. Valetto, S. Davies, and C. Williams, "An Analysis of Congruence Gaps and Their Effect on Distributed Software Development", Socio-Technical Congruence Workshop at ICSE, Leipzig, Germany, 2008

[P2] J. D. Herbsleb and A. Mockus, "An empirical study of speed and communication in globally distributed software development," *IEEE Transactions on Software Engineering*, vol. 29, pp. 481-494, 2003

[P3] N. Ramasubbu, M. Cataldo, R. K. Balan, and J. D. Herbsleb, "Configuring global software teams: a multi-company analysis of project productivity, quality, and profits," ICSE, Waikiki, Honolulu, HI, USA, 2011

[P4] A. Gopal, J. A. Espinosa, S. Gosain, and D. P. Darcy, "Coordination and performance in global software service delivery: The vendors perspective," *IEEE Transaction on Engineering Management*, vol. 58, pp. 772-785, 2011

[P5] J. Kotlarsky, P. C. van Fenema, and L. P. Willcocks, "Developing a knowledge-based perspective on coordination: The case of global software projects," *Information and Management*, vol. 45, pp. 96-108, 2008

[P6] J. A. Espinosa, N. Ning, and E. Carmel, "Do Gradations of Time Zone Separation Make a Difference in Performance? A First Laboratory Study”, ICGSE, pp. 12-22, 2007

[P7] J. A. Espinosa, S. A. Slaughter, R. E. Kraut, and J. D. Herbsleb, "Familiarity, complexity, and team performance in geographically distributed software development," *Organization Science*, vol. 18, pp. 613-630, 2007

[P8] J. A. Colazo and Y. Fang, "Following the Sun: Temporal dispersion and performance in open source software project teams". *Journal of the Association of Information Systems*, vol. 11, pp. 684-707, 2010

[P9] J. A. Espinosa, W. DeLone, and G. Lee, "Global boundaries, task processes and IS project success: A field study," *Information Technology and People*, vol. 19, pp. 345-370, 2006

[P10] M. Sumner, J. Molka-Danielsen, “Global IT Teams and Project Success”, Computer Personnel Research Conference, Vancouver, Canada, 2010

[P11] T. Nguyen, T. Wolf, and D. Damian, "Global software development and delay: Does distance still matter?”, ICGSE, pp. 45-54, 2008

[P12] M. Hoegl, H. Ernst, and L. Proserpio, "How teamwork matters more as team member dispersion increases," *Journal of Product Innovation Management,* vol. 24, pp. 156-165, 2007

[P13] K. M. Chudoba, E. Wynn, M. Lu, and M. B. Watson-Manheim, "How virtual are we? Measuring virtuality and understanding its impact in a global organization," *Information Systems Journal*, vol. 15, pp. 279-306, 2005

[P14] M. Cataldo, P. A. Wagstrom, J. D. Herbsleb, and K. M. Carley, "Identification of coordination requirements: implications for the Design of collaboration and awareness tools," Computer supported cooperative work, Banff, Alberta, Canada, 2006

[P15] S. Narayanan, S. Balasubramanian, and J. M. Swaminathan, "Managing Outsourced Software Projects: An Analysis of Project Performance and Customer Satisfaction," *Production and Operations Management*, vol. 20, pp. 508-521, 2011

[P16] S. Feczak and L. Hossain, "Measuring coordination gaps of open source groups through social networks”, International Conference on Information Systems, pp. 84-90, Missouri, USA, 2010

[P17] D. Šmite, N. B. Moe, and R. Torkar, "Pitfalls in remote team coordination: Lessons learned from a case study”, *LNCS*, vol 5089, pp. 345-359, 2008

[P18] C. D. Cramton and S. S. Webber, "Relationships among geographic dispersion, team processes, and effectiveness in software development work teams," *Journal of Business Research*, vol. 58, pp. 758-765, 2005

[P19] M. Cataldo, J. D. Herbsleb, and K. M. Carley, "Socio-technical congruence: a framework for assessing the impact of technical and work dependencies on software development productivity", ESEM, Kaiserslautern, Germany, 2008

[P20] J. N. Cummings, J. A. Espinosa, and C. K. Pickering, "Spatial and temporal boundaries in global teams: Distinguishing where you work from when you work", *IFIP*, vol. 236, pp. 85-98, 2007

[P21] S. S. F. Merlo, and C. Francalanci, "The coevolution of organizatinoal structures in open sources and closed source projects”, Organizational Communications and Information Systems Division, Illinois, USA, 2009

[P22] M. J. Liberatore and W. Luo, “The effect of client - Consultant coordination on is project performance: An agency theory perspective”, Portland International Center for Management of Engineering and Technology, Portland, Canada, 2007

[P23] S. W. Chou and M. Y.He, "The factors that affect the performance of open source software development - the perspective of social capital and expertise integration", *Information Systems Journal*, vol. 21, pp. 195-219, 2011

[P24] A. Beckhaus, L. M. Karg, and D. Neumann, "The impact of collaboration network structure on issue tracking's process efficiency at a large business software vendor", HICSS, Hawaii, USA, 2010.

[P25] M. V. Rini van Solingen, "The Impact of Number of Sites in a Follow the Sun setting on the Actual and Perceived Working Speed and Accuracy: A Controlled Experiment", ICGSE, Princeton, NJ, USA, 2010

[P26] A. Gopal and S. Gosain, "The role of organizational controls and boundary spanning in software development outsourcing: Implications for project performance," *Information Systems Research*, vol. 21, pp. 960-982, 2010

[P27] J. Alberto Espinosa, J. N. Cummings, and C. Pickering, "Time Separation, Coordination, and Performance in Technical Teams," *IEEE Transactions on Engineering Management*, vol. 59, pp 91-103, 2011

[P28] N. Ramasubbu, S. Mithas, M. S. Krishnan, and C. F. Kemerer, "Work dispersion, process-based learning, and offshore software development performance," *Management Information Systems*, vol. 32, pp. 437-458, 2008