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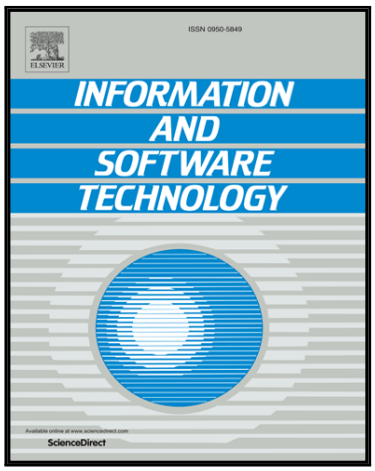

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Empirical Evidence in Follow the Sun Software Development: A Systematic Mapping Study

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Abstract
Context: Follow the Sun (FTS) development is a special case of Global Software Development. It is applied in the context of global projects to reduce the software development life-cycle duration. A number of studies have attempted to aggregate a better understanding of FTS development, but it is still an immature research area.
Objective: This paper aims to investigate the existing empirical evidence about FTS research with a focus on identifying what research has been conducted in the area and which results have been obtained.
Method: To achieve this goal, we performed a systematic mapping study to answer our research questions: "Which FTS studies have been published in the literature?" and "What empirical support is provided for them?" We investigated papers published between 1990 and 2017. The synthesis was made through classifying the papers into different categories (research topics, research methods, conferences and journals venues for FTS research, and countries involved in FTS research).
Results: We selected 57 papers using a predefined search strategy. The majority of the papers discussing FTS were published in the International Conference on Global Software Engineering (ICGSE). The main research topic addressed is processes and organization development for FTS. Case studies combined with the interview as a research sub-method is adopted in the most studies performed in FTS. The majority of the existing research and the most active researchers in this topic are from the United States and Brazil. However, India and the United States are the countries that appear most often in the studies conducted to investigate FTS.
Conclusion: Our findings suggest that FTS software development is an up-to-date research topic in Software Engineering. However, little information about FTS has been published over the last few years. The emergent need in this research is the development of evaluation research for testing FTS feasibility and effectiveness in practice.

Keywords: Global Software Development; Follow the sun; Time zone management; Virtual teams; Systematic mapping study.

1. Introduction

In the past few years, new technologies, solutions, and theories have been developed in the Software Engineering field. They have provided significant advances in terms of how teams should develop software. Nowadays, software is increasingly being developed by global teams. This is a new trend of producing software [1]. In companies of all sizes, projects are being set up across several development sites. These sites are separated by distance, time zones, and cultural differences [2]. Such software development is called Global Software Development (GSD).

GSD research focuses on studying aspects of software development of global scale. The GSD phenomenon began in the early 1990s and has become a powerful competitive strategy over the past 10 years [3, 4]. Since that time, studies have been offering an understanding about GSD, but it is still considered an immature research area [5].

In the software industry, many companies run globally distributed projects to benefit from

cheaper, faster, and better development of software systems, products, and services [6]. Furthermore, companies are implementing GSD to remain competitive in the software industry [7]. Large and small software companies put a lot of effort to successfully implement GSD projects [8]. Several factors have contributed to the growth of this phenomenon, such as, to take advantage of time-to-market, expertise and talent pools, wherever they may be located in the world [9].

The globalization of software development enables companies to create new strategies. These software development strategies explore the main characteristics of GSD. Temporal distance between development sites in GSD offers the opportunity to implement Follow the Sun (FTS) development [10].

FTS is a special case of GSD where software development is distributed over a twenty-four hour working day [11]. The FTS concept can be described as a set of two or more geographically and temporally dispersed software development teams, all working on the same phase of a project during their working hours pertaining to their time zone. However, in some cases, FTS teams have to be flexible to achieve overlap time with remote colleges. The main goal of FTS is to reduce the overall development time or time-to-market [11]. It is an alternative for GSD projects when trying to manage temporal distances between sites.

Large-scale companies are looking for a FTS global delivery model to optimize their software development resources and accelerate time-to-market. However, the adoption of FTS development requires careful planning. In recent years, several studies have investigated FTS in the context of software development, but this is still a topic with several open questions. Thus, this study investigates FTS research with a focus on identifying what research has been conducted in the area, and its results and research opportunities for the area. We designed a framework that specifies where current evidence is lacking and facilitates the identification of research gaps in FTS development. This study extends studies published by Kroll et al. [12] and Kroll et al. [13] and provides new information about FTS. Kroll et al. [12] conducted a mapping study of the literature in GSD to identify best practices for FTS development. They limited their study to identify practices conducted in GSD and which were, at the same time, recommended for FTS. Kroll et al. [12] provides new information about FTS best practices and challenges. In this current paper, we substantially extend the empirical evaluation of FTS that was conducted in those previous studies.

We conducted a Systematic Mapping Study (SMS) as our research method. The SMS was conducted from March to May 2017 following the protocol defined by Petersen et al. [14, 15]. We also adopted their study to build a classification scheme to categorize studies.

The remainder of this paper is organized as follows: Section 2 gives background and summarizes related work; Section 3 details the research method, planning, and execution; The results of this study are presented in Section 4; Section 5 provides discussion and observation around results provided in section 4; and finally, we draw conclusions and present future research directions in Section 6.

2. Background

Being enticing and even risky, FTS has always been the temptress of time zones [16]. Many companies have tried to implement FTS, but have abandoned it at some point because of the difficulty of putting it into practice [17]. In the literature, few studies provide evidence of the successful implementation of FTS in software projects. Prikladnicki and Carmel [16] argue that software companies are eager to implement FTS, but the lack of solutions to close theory and practice makes it difficult. To Solingen and Valkema [18], FTS is a promising way for software development. However, well-founded knowledge of its success is rare.

2.1 Follow the Sun software development

Global Software Development (GSD) is defined as a type of software development that addresses software engineering activities performed by globally distributed teams [6]. It is characterized by moving centralized software development to dispersed teams or external organizations in remote locations. GSD involves the development of software through the interaction of people, organizations, and technology across nations with different backgrounds, languages and working styles [1].

FTS is a special case of GSD in which team members are geographically distributed in different time zones [11]. Thus, software development can be undertaken over a 24-hour workday. FTS was originally developed to provide 24-hour customer service coverage, and has more recently been widely adopted by software development companies around the globe.

In FTS development, at the beginning and at the end of each workday shift there is a handoff. Handoff is a term adopted in the literature to define the process for transition from one site to another [11]. Handoffs are performed on a daily basis to present a status update and to pass on unfinished tasks (project source) from one site to another. The next site will take these tasks in order to start its workday shift [20].

As team members are distributed across multiple time zones, organizations can develop software continuously for 24 hours. Thus, the development duration may be theoretically reduced by 50% if there are two sites and by 67% if there are three sites [20]. However, when the number of sites in a daily cycle increases, on average, the overall working speed of the sites also increases [18].

Performing handoffs creates dependencies between production sites [17]. The team that will be starting the workday shift depends on the status update and project source from the last production site. In the literature, handoff management is mentioned as one of the main challenges in implementing FTS projects [11].

Carmel [11] describes that a project must satisfy the following conditions to be considered an FTS project:

- At least two sites separated by time zones;
- High dependency between sites;
- Project set up with the objective of reducing duration;
- Successfully achieves duration reductions.

In the literature, FTS is also referenced as ‘round-the-clock’. Although these terms are used in a similar way, their definitions are different. FTS is about speeding up and cutting down project duration by working in the same software development phase, while round-the-clock and others are about 24-hour coverage, running different operations on all shifts, and in different software development phases. Both of these concepts use time zone differences to design shifts, but for different purposes, and with different kinds of tasks [11].

2.2 Related work

Carmel et al. [17] provides a conceptual foundation and a formal definition of FTS. Even though this study is not a systematic literature review, the authors summarize findings from the literature. The authors also analyze the conditions under which FTS can be successful in reducing the duration of software development. Based on fundamental issues surrounding FTS, they developed 12 research propositions, such as: calendar efficiency, development method, product architecture and handoff efficiency, within-site coordination, cross-site coordination, and personal productivity.

In addition, the paper authors have been involved in prior research upon which this current study is built. Kroll et al. [12] conducted a mapping study to identify software practices

applied in 24-hour development projects. This study identified nine best practices and key aspects of FTS implementation. In the conclusions, the authors encouraged researchers to undertake more studies to investigate practices and processes for FTS implementation. Kroll et al. [13] extends the study published by Kroll et al. [12], providing new information about FTS best practices and challenges. They substantially extend the empirical evaluation of FTS and present 36 best practices and 17 challenges for FTS implementation.

3. Research Method

We conducted a Systematic Mapping Study (SMS) following the recommendations defined by Petersen et al. [14, 15]. Based on the perceived need for conducting this study in FTS, the research questions (RQ) for this study are as follows:

- RQ1: Which FTS studies have been published in the literature?
    - RQ1.1: When and where were the FTS research papers published?
    - RQ1.2: What FTS research topics are addressed?
    - RQ1.3: What are the research gaps addressed in FTS topics?

- RQ2: What empirical support is provided for the FTS topics addressed?
    - RQ2.1: Which are the adopted research methods?
    - RQ2.2: Which countries are involved in FTS research?

For each main research question, we formulated sub-questions as listed above. Those sub-questions are answered to support our main questions. In RQ1, we aim to identify and better understand the existing research in FTS. In RQ2, we aim to find out how the research has been performed in FTS.

To answer the research questions, we searched studies through seven digital libraries: IEEE Explore, ACM Digital Library, Wiley Inter Science Journal Finder, Elsevier Science Direct, Springer Link, ISI Web of Knowledge, and Engineering Village. For each digital library, query strings were created according to the search tool.

In the literature, four other terms have been used to refer to FTS: 24-hour development model, 24-Hour Knowledge Factory Paradigm (24HrKF), round-the-clock, and shift work. Therefore, we used these terms as part of our search string to identify as many relevant papers as possible. We also included other terms related to FTS theory such as time-zone flexibility and handover as part of our search. Since some databases limit the number of terms that can be used in a Boolean search expression, we create more than one Boolean search expression to conduct our search. The search was conducted using the Boolean search expressions shown in Table 1. We applied each Boolean search expression individually.

Id.	Boolean search expression
A	*("follow-the-sun") OR ("follow the sun")*
A1	*((("follow-the-sun") OR ("follow the sun")) and software)*
A2	*((("follow-the-sun") OR ("follow the sun")) and "global software development")*
B	*("round-the-clock") OR ("around-the-clock")*
B1	*("round-the-clock") OR ("around-the-clock") AND software*
B2	*((("round-the-clock") OR ("around-the-clock")) AND ("software development"))*
B3	*((("round-the-clock") OR ("around-the-clock")) AND ("Global software development"))*

C	*("24-hour development") OR ("24-Hour Knowledge Factory Paradigm") OR ("24 hour development") OR ("24 Hour Knowledge Factory Paradigm") OR ("24 Hour Knowledge") OR ("24-Hour Knowledge") OR ("24 hour") OR ("24-hour")*
C1	*("24-hour development") OR ("24-Hour Knowledge Factory") OR ("24 hour development") OR ("24 Hour Knowledge") OR ("24-Hour Knowledge")*
C2	*((("24-hour development") OR ("24-Hour Knowledge Factory Paradigm") OR ("24 hour development") OR ("24 Hour Knowledge Factory Paradigm") OR ("24 Hour Knowledge") OR ("24-Hour Knowledge") OR ("24 hour") OR ("24-hour")) AND ("global software development"))*
C3	*((("24-hour development") OR ("24-Hour Knowledge Factory Paradigm") OR ("24 hour development") OR ("24 Hour Knowledge Factory Paradigm") OR ("24 Hour Knowledge") OR ("24-Hour Knowledge") OR ("24 hour") OR ("24-hour")) AND ("software development"))*
D	*"shift work"*
D1	*(("shift work") and "software development")*
D2	*(("shift work") and "global software development")*
D3	*(("shift work") AND ("software"))*
E	*("time-zone flexibility") OR ("time zone flexibility")*
F	*((("handover") OR ("handoff") OR ("hand over") OR ("hand-off")) AND software)*
F1	*(((("handover") OR ("handoff") OR ("hand over") OR ("hand-off")) AND "software development"))*
F2	*((("handover") OR ("handoff") OR ("hand over") OR ("hand-off")) AND "global software development")*

Table 1. Boolean search expressions.

The selection of studies is one of the most critical processes in an SMS. It requires a great effort in the papers selection to prevent inaccuracy in the findings. We read all papers' title, abstract and in some cases, when the information provided in the title or abstract was not enough to take a selection decision, we read the full paper. After this extensive data search, we came up with 2406 papers. We then excluded panels, presentation and summary studies. Repeated papers and the ones that did not belong to software engineering or are not FTS studies were also excluded. We followed the definition given by Carmel [11] to select FTS studies: "*FTS is about speed, or more precisely, about reducing the calendar duration of a project. In FTS work, unfinished work is handed off to the next site on a daily basis. The FTS sites are very dependent on one another because they are couple, while sites in round-the-clock are not* [11]".

At this point, at least one author read the full paper. The final number of papers was reduced to 57. The numbers of papers found for each resource are listed in Table 2.

Digital library	**Boolean search expressions and results**	**Total results found**	**Not selected**	**Final selection**
IEEE Xplore	*A (40 results); B (237 results); C1 (3results); D (26 results); E (0 results); F1 (16 results)*	322	296	26
ACM Digital Library	*A (2 results); B1 (15 results); C1 (176 results) D (8 results); E (0 results); F (129 results)*	330	320	10
Wiley Inter Science Journal Finder	*A (441 results); B3 (13 results); C2 (19 results); D2 (3 results); E (0 results); F2 (26 results)*	502	499	3
Elsevier Science Direct	*A1 (290 results); B3 (5 results); C1 (0 results); D1 (71 results); E (1 results); F2 (26 results)*	393	390	3

Springer Link	*A2 (38 results); B3 (37 results); C1 (40 results); D1 (109 results); E (1 results); F2 (57 results)*	282	280	2
ISI Web of Knowledge	*A (78 results); B2 (10 results); C1 (10 results); D3 (28 results); E (0 results); F1 (14 results)*	140	137	3
Engineering Village	*A (138 results); B3 (10 results); C3 (242 results); D3 (9 results); E (0 results); F1 (38 results)*	437	427	10
Total		2406	2349	57

Table 2. Paper selection.

The SMS includes studies published between 1990 and 2017. According to Smite et al. [6], studies in GSD began to be published in the early 1990's. In Table 3, we present the number of papers published by year.

Year	**Number of papers**
1990, 1991, 1992, 1993, 1994, 1995	0
1996	2
1997	2
1998, 1999, 2000, 2001	1
2002	2
2003	1
2004	1
2005	2
2006	8
2007	5
2008	1
2009	7
2010	4
2011	4
2012	5
2013	4
2014	4
2015	1
2016	3
2017 (until May)	0

Table 3. Papers by year.

As a part of addressing our research questions, we used the classification schema of research approaches provided by Petersen et al. [14]. A short description of each category in the classification scheme, which was considered in this study, is provided below.

- Validation research: techniques or solutions investigated that have not yet been implemented in practice.
- Evaluation research: techniques and solutions implemented in practice, where an evaluation of the technique was conducted.
- Solution proposal: a proposal of a solution to a problem. This solution can be an extension of an existing technique.
- Philosophical papers: presents new things by structuring the field in the form of a taxonomy or conceptual framework.
- Opinion papers: the personal opinion of somebody on the usefulness of a certain technique, methodology or topic.
- Experience papers: reports the practical experience in a specific topic.

The methodological descriptions obtained in reading of the studies were classified based on the source evidence described by Smite et al. [22]. This study gives a classification schema and its categorization for GSD-related empirical studies. For example:

- Research method: Characteristics and aspects of software engineering work used in investigated studies;
- Research sub-method: Factors that refer to the origin and perspective of empirical data used to derive reported findings;
- Study background: Factors that differentiate GSD scenarios and thus classify the origin of reported findings.

We created a data extraction form using MS Excel to categorize the necessary information about study characteristics and findings from the included studies. Metadata including author, title, year, conference name, research method, and publication source with descriptive data fields such as, topic, gaps, and study characteristics were collected.

Data extraction needs to be as unbiased and reliable as possible. However, it is prone to human error and often subjective decisions are required. The main threats to the validity of the process of this study are the paper selection, inaccuracy in data extraction, incorrect classification of studies, research methods and types, and potential author bias. In order to ensure that process of selection in data extraction was unbiased, we followed Peterson et al. [14, 15] recommendations. Peterson et al. [14, 15] defines a method to build a classification scheme, and structure a software engineering field of interest. They describe and provide guidelines on how to conduct a systematic mapping study in software engineering. We also have discussed our results during academic seminars and with other researchers.

Relating the terms used to search studies, we assume that there is no consolidated definition for FTS. We followed the definition given by Carmel [11] to select studies in the final round of searching.

Different databases use different terminologies for FTS, so we have included most of the keywords used to represent FTS (see Table 1). We also adopted two approaches to evaluate the search. First, we made modifications in the inclusion criteria based upon findings of the initial literature searches. Here, we compared the search findings with a control group of papers, i.e. a set of known studies previously established by the researchers. Second, we decided to prioritize the search that comprised the "best evidence" set.

Regarding the study's classification and findings, at least two researchers discussed each paper. In the case of a disagreement, the issue was discussed until a consensus was reached. In cases where there was no consensus or there was doubt, the study was included to avoid premature exclusion. Therefore, a potential limitation for this study is that there is a possibility that the extraction process may have resulted in some inaccurate data being included.

4. Results

This section reports the results from the research questions defined for this study.

4.1 RQ1 – Which FTS studies have been published in the literature?

To answer RQ1, we present the papers identified in Table 4. We found 32 studies reported in 57 papers.

We reference the papers included in our study and listed in Table 4 with 'S' and a study number, e.g., [S15]. Where there is more one paper reporting the same study, we follow this with a letter referring to the particular paper, e.g., [S15b]. We organize the results by year followed by study number.

N.	Study and paper	Year	Authors and title
1	S1	1996	Gorton, I., Hawryszkiewycz, I., Fung, L. “Enabling Software Shift Work with Groupware: A Case Study Development Trial: Planning and. Systems Engineering”, Proceedings of the 29th Hawaii International Conference on System Sciences, vol 3, Collaboration Systems and Technology (HICSS '96), p.72.
2	S1a	1996	Gorton, I., Motwani, S. “Issues in co-operative software engineering using globally distributed teams”, Information and Software Technology, vol. 38, issue 10, pp. 647-655.
3	S1b	1997	Gorton, I., Hawryszkiewycz, I., Ragoonaden, K. “Collaborative tools and processes to support software engineering shift work”, BT Technology Journal, pp. 189-198.
4	S2	1997	Carmel, E. “Thirteen assertions for globally dispersed software development research”, Proceedings of the Thirtieth Hawaii International Conference on System Sciences, Wailea, HI, pp. 445-452 vol.3.
5	S3	1999	Grinter, R.E., Herbsleb, J.D. & Perry, D.E. “The geography of coordination: dealing with distance in R&D work”, Proceedings of the GROUP'99, Phoenix, AZ, USA.
6	S4	2002	Ramesh, V., Dennis, A. “The object oriented team: Lessons for virtual teams from global software development”, Proceedings of the 35th Annual Hawaii International Conference on System Sciences (HICSS’02), vol. 1, p. 18.
7	S5	2002	Taweel, A., Brereton, O.P. “Developing software across time zone: an exploratory empirical study”, Informatics, 26 (3), pp. 333–344.
8	S6	2003	Espinosa, J. A., Carmel, E. “The impact of time separation on coordination in global software teams: a conceptual foundation”, Software Process: Improvement and Practice, 8 (4), pp. 249-266.
9	S6a	2004	Espinosa, J. A., Carmel, E. “The Effect of Time Separation on Coordination Costs in Global Software Teams: A Dyad Model”, Proceedings of the 37th Annual Hawaii International Conference on System Sciences (HICSS'04), vol. 1, p. 10043.
10	S7	2005	Djavanshir, G. R. “Surveying the risks and benefits of IT outsourcing”, IT Professional, vol. 7, no. 6, pp. 32-37.
11	S8	2005	Yap, M. “Follow the sun: distributed extreme programming development”, Proceedings of the Agile Conference, pp. 218- 224.
12	S9	2006	Jalote, P., Jain, G. “Assigning tasks in a 24-h software development model”, Journal of Systems and Software, 79, 7, pp. 904-911.
13	S6b	2006	Espinosa, J. A., Pickering, C. “The Effect of Time Separation on Coordination Processes and Outcomes: A Case Study”, Proceedings of the 39th Hawaii International Conference on System Sciences (HICSS’06), pp. 25-35.
14	S10	2006	Setamanit, S., Wakeland, W., Raffo, D. “Exploring the Impact of Task Allocation Strategies for Global Software Development Using Simulation”, Proceedings (LNCS 3966), Springer, Berlin, Heidelberg, pp 274–285.
15	S11	2006	Spinellis, D. “Global software development in the FreeBSD project”, Proceedings of the International Workshop on Global Software Development for the Practitioner (GSD ‘06) (Shanghai, China), 73–79.
16	S12	2006	Treinen, J. J., Miller-Frost, S. L. “Following the Sun: Case Studies in Global Software Development”, IBM Systems Journal, 45 (4).
17	S6c	2006	Carmel, E. “Building your Information Systems From the Other Side of the World: How Infosys manages time differences”, MIS Quarterly Executive, 5 (1).
18	S5a	2006	Taweel, A., Brereton, P. “Modeling Software Development across Time Zones”, Information and Software Technology, 48, pp. 1-11.
19	S13	2006	Holmstrom, H., Conchuir, E. O., Agerfalk, P. J., Fitzgerald, B. “Global Software Development Challenges: A Case Study on Temporal, Geographical and Socio-Cultural Distance”, Proceedings of the International Conference on Global Software Engineering (ICGSE '06), pp. 3-11.
20	S14	2007	Espinosa, J. A., Nan, N., Carmel, E. “Do Gradations of Time Zone Separation Make a Difference in Performance? A First Laboratory Study”, Proceedings of the International Conference on Global Software Engineering (ICGSE '07), pp. 27-30.
21	S15	2007	Gupta, A., Seshasai, S. “24-hour knowledge factory: Using Internet technology to leverage spatial and temporal separations”, ACM Trans. Internet Technol. 7, 3, Article 14.

22	S10a	2007	Setamanit, S., Wakeland, W., Raffo, D. “Improving Global Software Development Project Performance Using Simulation”, Systems Science, pp. 5-9.
23	S10b	2007	Setamanit, S., Wakeland, W., Raffo, D. “Using simulation to evaluate global software development task allocation strategies”, Software. Process: Improve. Practice, 12, pp. 491- 503.
24	S15a	2007	S. Seshasai and A. Gupta, "The Role of Information Resources in Enabling the 24 Hour Knowledge Factory", Information Resource Management Journal, vol. 20, pp. 105-127.
25	S15b	2008	Denny, N., Mani, S., Seshu, R., Swaminathan, M., Samdal, J. “Hybrid Offshoring: Composite Personae and Evolving Collaboration Technologies”, Journal of Information Technology Review, Vol. 21, Issue 1, pp. 89-104.
26	S16	2009	Conchuir, E. O., Agerfalk, P. J., Holmstrom, H., Fitzgerald, B. “Global software development: where are the benefits?”, Communication. ACM 52, 8, pp.127-131.
27	S17	2009	Doma, S., Gottschalk, L., Uehara, T., Liu, J. “Resource Allocation Optimization for GSD Projects”, Computational Science and Its Applications (ICCSA), vol 5593, pp. 13–28.
28	S18	2009	Visser, C., Solingen, R. V. “Selecting Locations for Follow-the-Sun Software Development: Towards A Routing Model”, Proceedings of the International Conference on Global Software Engineering (ICGSE '09), pp.185 -194.
29	S14a	2009	Carmel, E., Dubinsky, Y., Johnston, J. “Follow the sun workflow in global software development: Theory, modelling and quasi-experiment to explore its feasibility”, In Proceedings of the Third Global Sourcing Workshop: The Impacts of Global IS Sourcing on Engineering, Technology and Innovation Management, Keystone, CO, USA.
30	S14b	2009	Carmel, E., Espinosa, A., Dubinsky, Y. “Follow The Sun Software Development: New Perspectives, Conceptual Foundation, and Exploratory Field Study”, Proceedings of the 42nd Hawaii International Conference on System Sciences (HICSS’09), pp.1-9.
31	S15c	2009	Gupta, A., Mattarelli, E., Seshasai, S., Broschak, J. “Use of collaborative technologies and knowledge sharing in co-located and distributed teams: Towards the 24-h knowledge factory”, The Journal of Strategic Information Systems, vol. 18, 147-161.
32	S16a	2009	Conchuir, E. O., Holmstrom-Olson, H., Agerfalk, P. J., Fitzgerald, B. "Benefits of global software development: Exploring the unexplored", Software Process Improvement and Practice, 14(4), pp. 201–212.
33x	S19	2010	Lamersdorf, A., Münch, J. “A multi-criteria distribution model for global software development projects”, J Brazil Comp Soc., vol. 16, pp. 97-115.
34	S14c	2010	Carmel, E., Espinosa, A., Dubinsky, Y. “Follow the Sun Workflow in Global Software Development”, Journal of Management Information Systems, vol. 27, no. 1, pp. 17 - 38.
35	S20	2010	Solingen, V. R., Valkema, M. “The Impact of Number of Sites in a Follow the Sun Setting on the Actual and Perceived Working Speed and Accuracy: A Controlled Experiment”, Proceedings of the 5th International Conference Global Software Engineering (ICGSE’05), pp.165 -174.
36	S15d	2011	Gupta, A., Crk, I., Bondade, R. “Leveraging temporal and spatial separations with the 24-hour knowledge factory paradigm”, Information Systems Frontiers 13, 3, pp. 397- 405.
37	S21	2011	Hess, E. R., Audy, J. L. N. “Challenges in the Follow-the-Sun strategy: How to alleviate them”, Proceedings of the Americas Conference on Information Systems (AMCIS), Paper 213.
38	S22	2011	Kroll, J., Hess, E. R., Audy, J. L. N., Prikladnicki, R. “Researching into Follow-the-Sun Software Development: Challenges and Opportunities”, Proceedings of the 6th International conference on Global Software Engineering (ICGSE’11), Helsinki, Finland, pp. 60-65.
39	S23	2011	Tang, J. C., Zhao, C., Cao, X, Inkpen, K. “Your time zone or mine?: a study of globally time zone-shifted collaboration”, Proceedings of the ACM 2011 Conference on Computer supported cooperative work (CSCW '11), pp. 235-244.
40	S24	2011	Czekster, R. M., Fernandes, P., Prikladnicki, R., Sales, A., Santos, A. R., Webber, T. “Follow-the-Sun Methodology in a Stochastic Modelling Perspective”, Proceedings of the 6th International Conference on Global Software Engineering Workshop, pp. 54–59.
41	S25	2012	Kroll, J., Audy, J. L. N. “Mapping Global Software Development Practices for Follow-the-Sun Process”, Proceedings of the 7th International Conference on Global Software Engineering (ICGSE), pp. 164-168.
42	S26	2012	Kroll, J., Audy, J. L. N. “Follow-the-Sun Strategy: A Process for Global Software Development”, Proceedings of the 7th International Conference on Global Software Engineering Workshops, pp. 76–78.

43	S27	2012	Kroll, J., Santos, A. R., Prikladnicki, R., Hess, E. R, Glanzner, R., Sales, A., Audy, J. L. N., Fernandes, P. "Follow-the-Sun Software Development: A Controlled Experiment to Evaluate the Benefits of Adaptive and Prescriptive Approaches", Proceedings of the 24th International Conference on Software Engineering & Knowledge (SEKE), pp. 551-556.
44	S24a	2012	Santos, A. R., Sales, A, Fernandes, P. "Setting Up a Stochastic Model for Teams Working in a Follow-the-Sun Environment", Proceedings of the 7th International Conference on Global Software Engineering (ICGSE), p.179.
45	S21a	2012	Hess, E. R., Audy, J. L. N. "FTSProc: A Process to Alleviate the Challenges of Projects that Use the Follow-the-Sun Strategy", Proceedings of the 7th International Conference on Global Software Engineering (ICGSE'12), pp. 56-64.
46	S28	2013	Prikladnicki, R., Carmel, E. "Is time-zone proximity an advantage for software development? The case of the Brazilian IT industry", Proceedings of the International Conference on Software Engineering (ICSE '13), pp. 973-981.
47	S27a	2013	Kroll, J., Hashmi, S. I., Richardson, I., Audy, J. L. N. "A Systematic Literature Review of Best Practices and Challenges in Follow-the-Sun Software Development", Proceedings of the 8th International Conference on Global Software Engineering Workshops (ICGSEW), pp. 18 - 23.
48	S26a	2013	Kroll, J., Audy, J. L. N. "Adopting Agile Methods for Follow-the-Sun Software Development", Proceedings of the 19th Americas Conference on Information Systems (AMCIS), Chicago, Illinois.
49	S26b	2013	Kroll, J., Prikladnicki, R., Audy, J. L. N., Carmel, E., Fernandez, J. "A Feasibility Study of Follow-the-sun Software Development for GSD Projects", Proceedings of the International Conference on Software Engineering (SEKE), pp.196-199.
50	S29	2014	Kroll, J., da Silva Estacio, B. J., Audy, J. L. N., Prikladnicki, R. "An Initial Framework for Researching Follow-the-Sun Software Development", Proceedings of the International Conference on Global Software Engineering (ICGSE), pp.116-124.
51	S26c	2014	Kroll, J., Richardson, I., Audy, J. L. N. "FTS-SPM: A Software Process Model for Follow the Sun Development: Preliminary Results", Proceedings of the International Conference on Global Software Engineering Workshops (ICGSEW), pp.21-26.
52	S26d	2014	Kroll, J., Richardson, I., Audy, J.L.N. "Proposing a Software Process Model for Follow the Sun Development", Proceedings of the 26th International Conference on Software Engineering and Knowledge (SEKE).
53	S26e	2014	Kroll, J., Richardson, I., Audy, J., L. N., Fernandez, J. "Handoffs Management in Follow-the-Sun Software Projects: A Case Study", Proceedings of the 47th Hawaii International Conference on System Sciences (HICSS), Hawai'i Island, USA.
54	S24b	2015	Santos, A. R., Sales, A., Fernandes, P. "Using SAN formalism to evaluate Follow-The-Sun project scenarios", Journal of Systems and Software, v.100, p.182-194.
55	S30	2016	Imtiaz, S., Ikram, N. "Dynamics of task allocation in global software development", J. Software. Evolution and Process 29(1)
56	S31	2016	Yu, L., Guan, Z., Ramaswamy, S. "The effect of time zone difference on asynchronous communications in global software development", International Journal of Computer Applications in Technology, v.53 n.3, p.213-225.
57	S32	2016	Tell, P., Babar, M. A. "An Empirical Evaluation of an Activity-Based Infrastructure for Supporting Cooperation in Software Engineering", Proceedings of the International Conference on Global Software Engineering (ICGSE), Irvine, CA, pp. 34-43.

Table 4. FTS studies.

4.1 RQ1.1 - When and where were the FTS research papers published?

To answer RQ1.1, we identified publishers, conferences, journals and publication year. The International Conference on Global Software Engineering (ICGSE) is the most popular conference for this research with 14 papers published between 2006 and 2016. The HICSS (Hawaii International Conference on System Sciences) is also a popular conference with 7 papers published between 1996 and 2014. The rest of the papers were distributed in 29 conference proceedings or journals. The proceedings of AMCIS (Americas Conference on Information Systems) and SEKE (International Conference on Software Engineering and Knowledge Engineering) each include two and three papers respectively. Table 5 provides details of the

papers' publication described in Table 4. Thirty-seven papers (65%) are conference proceedings, and 20 papers (35%) are journal papers.

Publisher	Conference/ Journal	Publication year	Number of papers
IEEE	ICGSE	2006, 2007, 2009, 2010, 2011 (2), 2012 (4), 2013, 2014 (2), 2016	14
	HICSS	1996, 1997, 2002, 2004, 2006, 2009, 2014	7
	AGILE	2005	1
	APSEC	2006	1
	ICSE	2013	1
	IEEE Computer Society (journal)	2009	1
	PICMET	2007	1
ACM	GROUP	1999	1
	GSE	2006	1
	IBM System Journal (journal)	2006	1
	SPW/ProSim (journal)	2006	1
	Communications of the ACM	2009	1
	ICCSA	2009	1
	JSIS (journal)	2009	1
	Information Systems Frontiers (journal)	2009	1
	JMIS (journal)	2011	1
	CSCW	2010	1
Wiley Inter Science	Journal of Software: Evolution and Process	2007, 2009, 2016	3
Elsevier Science Direct	IST (journal)	2006	1
	Global Sourcing Workshop	2009	1
	JSS (journal)	2015	1
Springer Link	BT Technology Journal (journal)	1997	1
	Journal of the Brazilian Computer Society	2010	1
ISI Web of Knowledge	IST (journal)	1996	1
	ACM Transactions on Internet Technology (TOIT) journal	2007	1
	International Journal of Computer Applications in Technology (IJCAT)	2016	1
Engineering Village	SEKE	2012, 2013, 2014	3
	Information Resource Management Journal (IRMJ)	2007, 2008	2
	AMCIS	2011, 2013	2
	Informatica (journal)	2002	1
	HICSS	2003	1
	MIS Quarterly (journal)	2006	1

Table 5. Conferences and journals venues for FTS research.

4.3 RQ1.2 - What FTS research topics are addressed?

To answer RQ1.2, we identify the main research topics and gaps addressed in each study. Research topics are defined as subjects of investigation in research papers. To identify them, we reviewed all papers looking for the main subject discussed in each paper. We did the same to identify the research gaps. However, a gap in the literature is an open research question within a given domain that has not been answered adequately in previous studies. It is an element for which insufficient information limits the ability to reach a conclusion for a question. We identified research gaps by looking for research questions that are not only unresolved but whose

exploration can meaningfully contribute to existing theory and/or practice. We use the research topic overview provide by Ebert et al. [23] to describe the research topics and gaps.

In Table 6, we present our results and a brief description of each study. As we can observe in Table 6, a research topic can have more than one research gap. In general, studies are performed to solve a problem or to investigate a new approach, technique or characteristic. Thus, we associate identified research gaps by mapping the research problems addressed in the papers.

Main research topic	Research gap	Study description
Collaboration, communication, control and distance	Coordination challenges in time-separated contexts	Discusses a coordination model for virtual teams [S6];
	Coordination in FTS is challenging because of lean communication media, fewer opportunities for spontaneous interaction, less contextual reference, and lack of other benefits of co-location	Proposes a collaboration model to help understand the consequences of time separation on coordination costs [S6a];
	Time zone coordination	Presents findings from a case study in which we explore the particular challenges associated with managing GSD [S13];
	The severe time zone offset beyond the typical workday makes it difficult to coordinate active collaborations across sites using conventional mechanisms such as synchronous meetings and unplanned calls	Describes the results from interviews about global time zone differences [S23];
	Collaboration across time zones often involves modifications to the typical workday, with remote team members collaborating either very late at night or extremely early in the morning. Though this presents problems related to treating time zones as an impediment to productivity	Describes case studies in FTS development [S12];
Processes and Organization	The amount of communication overhead that is introduced can lead to negative consequence	Describes new models for knowledge representation considering the 24-hour knowledge factory [S15d]; Discusses the benefits of the 24-hour knowledge factory, problems of asynchronous communication, and introduces the composite persona concept [S15b];
	Effectiveness of virtual teams	Discusses how the software production process could be re-engineered to further exploit concurrent activities with globally distributed teams [S1a];
	Feasibility	Investigates the feasibility of FTS to develop a software project [S26b];
	Project execution	Describes best practices and challenges for FTS implementation [S25a] [S25]; Proposes a software model to support FTS development [S26c] [S26d]; Explores elements of the FreeBSD global development model (including round-the-clock development) through a quantitative analysis of data obtained from the CVS

		repository [S11]; Discusses a stochastic model definition to evaluate the performance of different aspects of FTS projects [S24b];
	Few GSD projects have been able to realize the full benefits of FTS development	Discusses information resource management for enabling 24-hour software development [S15a];
	Managing team processes and performing work in global virtual teams can be challenging	Describes a hybrid simulation model of the software development process that is specifically planned to examine GSD projects [S10a] [S10b]; Investigates coordination and communication processes in global virtual software development teams [S4];
Handoffs' development and management	Solutions for performing handoffs	Identifies the challenges related to the FTS strategy, and shows how to alleviate them [S21]; Proposes a process to perform daily handoffs [S21a]; Presents an infrastructure to support handoff activities based on the models of Activity Theory (AT) and the principles of the Activity-Based Computing (ABC) paradigm [S32];
	Coordination and knowledge sharing across time and space during handoffs are critical in the 24-hour knowledge factory model	Describes collaboration activities between members of a globally distributed team with the collaboration activities between co-located team members performing a similar task [S15c];
	Handoffs management	Describes management elements to perform handoffs [S26e];
Theoretical foundation	Theoretical foundation for FTS	Describes four models used to coordinate multi-site work which includes FTS model [S3]; Describes a set of propositions for the FTS development [S6b]; Describes benefits and risks [S7]; Presents a foundation for understanding FTS including: a definition, a description of its place in the life cycle, a discussion of choice of methodologies that are likely to make it successful [S14a]; Presents a foundation for understanding FTS including a definition, a description of its place in the life cycle, and choice of methodologies [S14b]; Describes FTS context-definitions and evolution [S14c]; Discusses challenges and research opportunities [S2] [S22] [S29];
	Software process for FTS implementation	Presents a research proposal for FTS [S26];
Development methodologies	For teams that are located in different places around the globe, a low level of interdependence would seem ideal as this reduces the problems and risks associated with long distance	Describes a software development trial to evaluate the use of a groupware support environment for widely geographically separated software development teams [S1];

	Development methodologies for FTS	Evaluates the benefits of adaptive and prescriptive approaches for FTS [S27]; Reports the experience using full Extreme Programming (XP) practices on a single codebase with distributed teams [S8];
	Feasibility of agile methods for FTS	Investigates the application of agile methods for FTS [S26a];
Task allocation	Different skills, culture, time zone	Presents a model to improve efficiency of the project development across remote areas [S17];
	Communication, technical, managerial, and coordination challenges	Presents a tool for task allocation [S1b];
	Tools and technologies to solve communication and coordination difficulties	Introduces a sequential collaborative software engineering process involving shift working across time zones and describes an exploratory empirical study of this working pattern [S5]; Presents an algorithm for task allocation [S9]; Presents a multi-criteria model for task allocation called TAMRI (Task Allocation based on Multiple cRIteria) [S19];
	Coordination of daily handoffs	Presents a simulation model for task allocation [S10]; Discusses the factors and their relative importance for the task allocation decision according to GSD practitioners [S30];
Project management	How to reduce time-to-market through 'round the clock' working	Identifies factors and constraints that influence time-to-market when software is developed across time zones [S5a];
	Team's performance	Identifies FTS' characteristics to build a stochastic model [S24]; Discusses a stochastic model definition to perform the evaluation of FTS projects [S24a];
Time zone management	How global companies coordinate time and distance for software development teams	Presents solutions for time zone management [S6c];
	Time separation and its effect on FTS development	Discusses time-zone effectiveness [S16] [S16a]; Investigates the effect of time zone differences through mining and investigating the Linux kernel mailing list archive. Statistical tests are used to analyze and identify correlations [S31];
	Coordination of time overlap, coordination challenges and its relationships.	Discusses time separation (overlap) between development sites [S14]; Discusses time zone proximity as an advantage for software development. Reports the Brazilian IT industry case [S28];
	The impact of increasing the number of sites in the FTS cycle on the quality of the work.	Discusses the impact of number of sites in FTS projects [S20];

	Deciding where to establish development locations is a strategic decision in the field of FTS software development.	Presents a model for selecting development locations [S18];
Tools and IT Infrastructure	Tools to support FTS implementation	Describes tools based on Internet technologies [S15].

Table 6. Research topics addressed in FTS studies.

Since authors of the papers define keywords to categorize a study, we also list a summary of keywords mentioned in FTS studies in Table 7.

Keyword	**Number of studies**	**(%)**
Global Software Development	23	40
Follow the Sun (also FTS)	20	35
Software engineering; task allocation; Virtual teams.	4	9
Best practices; Software process; Stochastic modelling.	3	7
24-hour software development; Challenges; Distributed software engineering; Global software engineering; Knowledge sharing; Performance Evaluation; Project scheduling; Projects simulation; Software practices; Software process; Time to market; Time zone management.	2	3
24-h Knowledge factory; 24-hour development; Accuracy; Adaptive approach; Agile methods; Asynchronous communications; Bayesian networks; Benefits; Best practice; Brazilian IT industry; Calendar efficiency; Collaborative Technologies; Collaborative work; Collaborative working; Coordination across time zones; Coordination mechanisms; Coordination costs; Data management; Dependency graph; Development across time zones; Development process; Distributed development; Distributed software development; Distributed teams; Distributed Work arrangements; Duration deduction; Empirical software engineering; Empirical study; Experiment; Framework; Geographic boundaries; Geographically dispersed teams; Geographically distributed development; Global coordination; Global development; Global software teams; Global teams; Global time zones; Global work; Globalization of IT; Globally distributed teams; Handoff efficiency; Hybrid simulation model; Interview study; IS Project Teams; Knowledge management; Knowledge representation; Mailing lists; Offshoring; Open source; Optimal schedule; Outsourcing; Perceived accuracy; Perceived working speed; Practitioners view; Project management; Quantitative analysis; Research challenges; Research method; Research variable; Resources' optimization; Shift work; Software development; Software engineer; Software process model; Software process simulation modelling; Survey; Temporal boundaries; Time separation; Time zone difference effects; Time zones; Time-shifted collaboration; Time-zone proximity; Uncertainties; Work assignment; Work distribution; Working speed; XP.	1	2
Keywords are not available	*18*	*57*

Table 7. Author keywords.

Most authors define Global Software Development as a keyword in FTS studies (40%). Follow the sun is the second most mentioned keyword in FTS papers (35%). Other keywords were defined less than five times by the authors. Eighteen studies (57%) do not present keywords.

4.4 RQ1.3 - What are the research gaps addressed in FTS topics?

To answer RQ1.3, Table 6 presents the research gaps addressed in FTS studies. We have identified a research gap where there were insufficient results presented on a research topic and no further publications which explained that the phenomena were subsequently found. Some studies, which report different research topics, have discussed the same research gap. We also noted relationships between research topics. For example, coordination and communication are research gaps in common in more than five research papers (S1b, S6, S15d, and S15c).

We summarize the key elements in FTS research in Figure 1. We categorized research gaps (RG) in research topics (RT). As we can see in Figure 1, RT2: Development process and RT3: Handoffs' development and management share RG7: Global virtual teams and RT4: Theoretical foundation and RT8: Time zone management share RG10: Time management

challenges. This demonstrates that research gaps have been investigated in studies under different research topics.

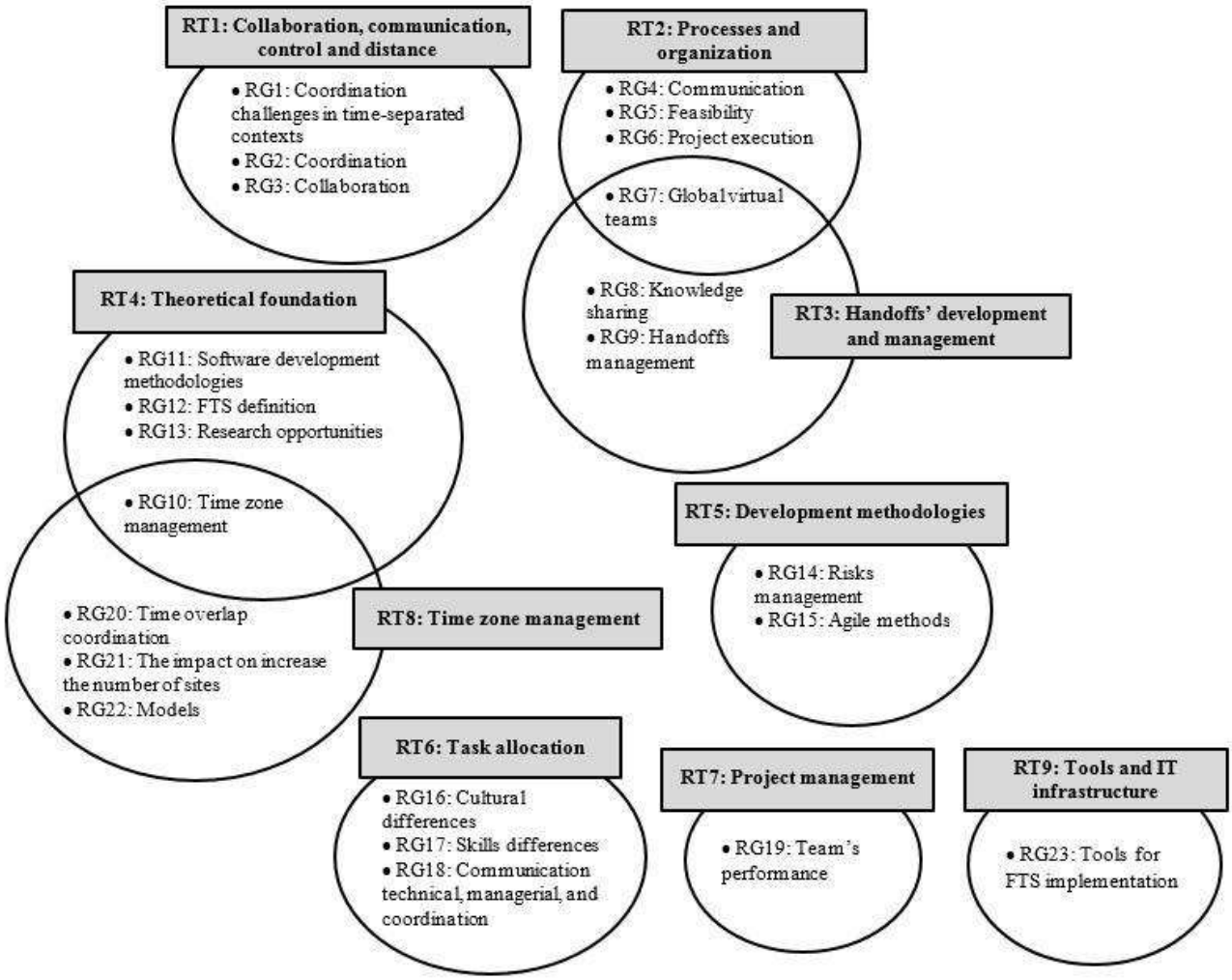

Figure 1. Research topics and gaps in FTS research.

Based on the analysis and results presented in Table 6 and Figure 1, we designed a framework that specifies where current evidence is lacking. The framework facilitates the identification of research gaps in FTS development and the relationship between them. We present the framework in Figure 2.

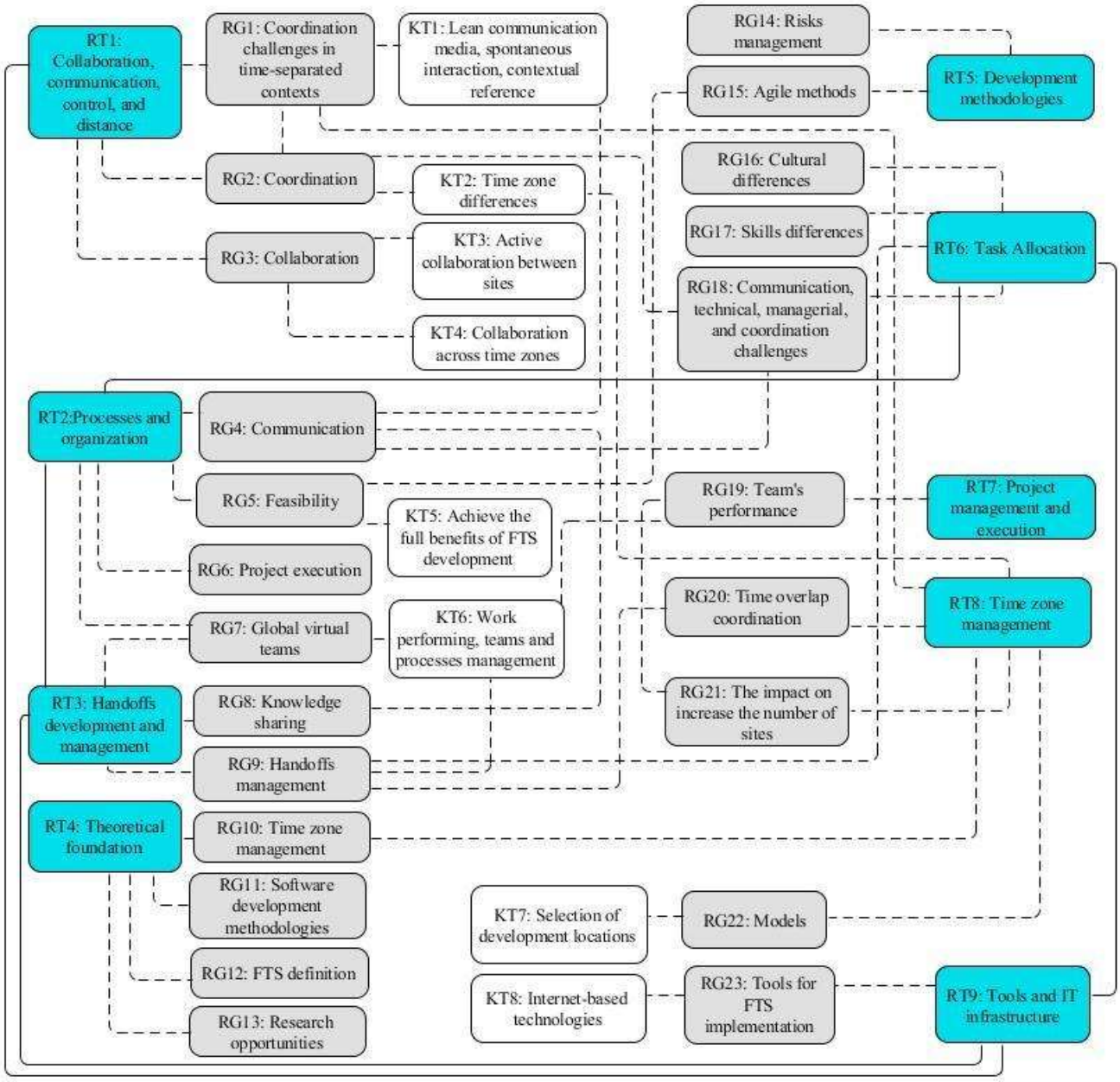

Figure 2. Research Gaps abstraction in FTS research.

The framework is composed of nine main research topics (RT), twenty-three main research gaps (RG) and eight key topics (KT). It is organized into three levels. The first level presents research topics, the second level presents the research gaps, and the third level presents the key topics.

Linking lines between elements in the framework shows that they have some relationship. The relationship can occur between one or more framework elements. For example, RG1: Coordination challenges in time-separated contexts, RG2: Coordination and RG3: Collaboration are research gaps related to RT1: Collaboration, communication, control, and distance. Dashed lines from research gaps to the key topics, shown in white boxes, shows that some research has been already conducted on that research gap. An example is research conducted in Internet-based technologies related to RG23. This study (S15) describes tools based on Internet technologies to support FTS development.

Some research gaps are related to one or more key topics. This is because a study can investigate more than one key topic when investigating a research gap. Key topics are those

addressed in FTS studies, which provides evidence on a research topic. The relationship between elements in the framework also occurs between research topics, as represented by a solid arrow in the framework. For example, RT2 is related to RT3. These research topics are dependent on the other (e.g. to fill the gaps related to RT2 it is needed first to address RT3).

The framework provides a classification showing where the current evidence falls and where the research gaps exist. Knowing where the gaps are and the reason(s) underlying their existence could help in the translation of these gaps into specific research needs, and subsequently, in the prioritization and design of appropriate further research.

4.5 RQ2 - What empirical support is provided for the FTS topics addressed?

To answer RQ2, the empirical approach adopted in FTS studies is summarized in Table 8. We organize the results by study, research method, and number of studies, research sub-method, and research type and study background.

4.6 RQ2.1 - Which are the adopted research methods?

FTS studies report results from case studies, literature reviews, controlled experiments, systematic literature reviews (SLR), simulations, and expert panel research methods. The most used combination of research methods and research sub-methods is the case study and interview. In the majority of the studies papers, case study is the empirical approach adopted, as shown in Table 8.

Study	**Research method**	**Number of studies**	**Research sub-method**	**Research type**	**Study background (Laboratory / Industry)**
S1, S1b, S4, S5, S5a, S6b, S6c, S7, S8, S9, S11, S12, S13, S16, S16a, S23, S26a, S26b, S26e, S28, S31	Case study	21	Interview (9) Interview and Observation (3) Questionnaire and Observation (3) Analyse of data repository (2) Not described (4)	Evaluation research (4) Experience papers (16) Solution proposal (1)	Industry
S1a, S2, S3, S6, S6a, S14c, S15, S15a, S15b, S15d, S18, S21, S24, S24a, S26,	Literature review	15	None (14) Simulation (1)	Experience papers (1) Solution proposal (8) Evaluation research (1) Opinion papers (1) Philosophical papers (4)	None
S14, S14b, S15c, S20, S27, S21a, S32	Controlled experiment	7	Experimental data and questionnaire (4) Interview (2) Not described (1)	Validation research (4) Experience papers (2) Evaluation research (1)	Laboratory (6) Laboratory and Industry (1)
S22, S25, S25a, S29	Systematic Literature Review	4	None	Philosophical papers (4)	None
S10, S10a, S10b, S17	Simulation	4	None	Solution proposal (3) Validation research (1)	Laboratory
S19, S30	Literature Review and Case study	2	Interview (1) Interview and questionnaire (1)	Validation research (1) Experience papers (1)	Laboratory and Industry (1) Industry (1)
S26c, S26d	Expert panel	2	None	Solution proposal (1) Validation research (1)	Industry

S24b	Literature Review, Case study and Controlled experiment	1	Experimental data and questionnaire	Solution proposal (1)	Laboratory
S14a	Systematic Literature Review and Controlled experiment	1	Experimental data and questionnaire	Solution proposal and Validation research (1)	Laboratory

Table 8. Empirical support for FTS research.

RQ2.2: Which countries are involved in FTS research?

To answer RQ2.2, we identified the research groups' location, the collaboration between them, and the geography of study locations. We performed a topic-specific classification based on Petersen et al. [14, 15] guidelines. In this type of classification scheme, topics can either be emerging from the study, or based on existing literature. Table 9 presents this information.

Research country	**Number of studies**	**Geography of study locations**
USA	19	North America and Western Europe (1), UK, USA and Singapore (1), USA, India, Canada, UK, Ireland, Philippines, Israel, Russia, and China (1), USA-Australia /USA-India (1), India (1), USA (2), none (12)
Brazil	11	India, Mexico, and Australia (3), None (8)
Brazil and Ireland	3	*Not available*
UK	3	Israel and UK (1), none (2)
Australia	2	Australia and India (1), None (1)
India	2	USA and India (1), India (1)
Ireland and Sweden	2	Ireland, India, USA (1), India, USA (1)
Netherlands	2	India (1), None (1)
Australia and Denmark	1	USA, UK, India, and Australia
Brazil, India, and USA	1	India, Mexico, and Australia
Brazil and USA	1	Brazil
Brazil, Ireland, and India	1	India, Mexico, and Australia
China and USA	1	Asia, Europe, and USA
Germany	1	Many sites
Greece	1	*Not available*
India and USA	1	*Not available*
Ireland	1	Ireland and USA
Israel and USA	1	USA
Italy	1	India and USA
Japan and USA	1	*Not available*
Pakistan	1	Pakistan, USA, UK, and Qatar

Table 9. Countries involved in FTS research.

The majority of studies were performed by researchers from the United States (44%), followed by researchers from Brazil (26%). The United States has collaborated in research with Brazil, India, China, Israel, and Japan. Brazilian researchers have collaborated with researchers in Ireland, India, and the United States. Given that the most active researchers in FTS are from the United States and Brazil (41 papers, 72%), this is not an unexpected result because Brazil is the location that appears in only one study.

India is the country that appears in the majority of studies conducted to investigate FTS. Sixteen studies mentioned that India is the study location followed by the United States (14 studies). The most used combination of study locations is between India and Australia (8 studies).

We also found studies reporting only one and two geographic locations, 7 and 6 studies respectively (23%). India is the location where studies on FTS settings and characteristics were conducted. In those studies with two locations, FTS has also been investigated to achieve different working speed.

5. Discussion

The results of this review have given us useful insight into the state of the art of research in the area of FTS software development. What is interesting to observe is that the number of studies in FTS has not increased in recent years. Less than eight FTS studies have been published per year since 2006. Based on our review, we cannot conclude that FTS is becoming more popular in the literature or in the software industry. However, we observe that FTS is an active research topic in GSD. We also can observe that there is no consensus about the FTS definition. Thus, literature can report FTS studies with different definitions and the research topic potentially changes.

FTS studies are more frequently reported in conferences than in journals. The International Conference on Global Software Engineering (ICGSE) and Hawaii International Conference on System Sciences (HICSS) are the most popular conferences for FTS. Other conferences have reported very few studies. With this result, we can only conclude that FTS is a topic that has attracted attention in the software engineering research community and in the information systems (IS) discipline.

Nine main research topics are addressed in FTS studies as shown in Table 6. The majority of the studies explore the development process, theoretical foundation and time zone management topics. However, there were no significant differences between the numbers of studies conducted in each research topic. We observe from this result, and from repetitions in the research gap content, that there is a need for studies to clarify the main characteristics of FTS. We highlight that significant research is still needed to establish FTS feasibility and effectiveness in different software development contexts.

Most of the papers we reviewed present Global Software Development (40%) and Follow the sun (35%) as keywords. This is due to FTS being a subset of GSD [11]. Seventy-eight keywords are defined only once among all FTS studies, which may indicate that previous research has not addressed these topics. Other evidence for this conclusion is that FTS literature does not report these keywords as research topics explored in FTS studies.

Overall, empirical support for FTS research is based on a combination of case study and interview methods. The majority of the existing research literature in FTS is based on experience papers (35%), and solution proposals (26%). However, we only found 5 papers (8%), which presented evaluation research. This reveals the need to conduct more evaluation on techniques and solutions described in FTS literature.

North American researchers authored 44% of the FTS papers, with the largest research group based in the United States. Brazilians are also active in FTS research, having authored the second largest number of studies in FTS (26%). However, we only find one study discussing FTS in practice in Brazil. India is the country most discussed in studies, followed by the United States.

Apart from answering the research questions, this study presents a framework that comprises research topics, research gaps and key topics in FTS research. Thus, we highlight further directions for research focused on the nine research topics described in Figure 2:

1. *Collaboration, communication, control, and distance:* research relating to strategies for improving collaboration, communication and control and reducing the temporal distance between FTS teams is needed for successfully implements FTS.
2. *Development process:* our results reinforce the importance of defining models, processes, and best practices for software development. Their definition of software

development is relevant for software engineering as well as for the software industry.

3. *Handoffs' development and management:* performing handoffs creates dependencies between sites. Handoffs require a large coordination, communication and collaboration effort. Furthermore, handoffs must be fast and efficient in order to reduce the development cycle duration. Coordination difficulties can negatively affect team productivity and consequently will not result in benefits for the project. Linked to this is the difficult matter of how to demonstrate the efficiency to share knowledge between sites during handoffs.
4. *Theoretical foundation:* the development of new theories could help addressing knowledge gaps in FTS research. Misunderstandings in the definition of FTS lead to studies that do not address FTS characteristics. Besides that, theoretical foundations are the basis for conducting future research in an area. There needs to be a better understanding of theory and practice in FTS, an emerging research topic, to achieve the desired result.
5. *Development methodologies:* methodologies such as Scrum and XP have been used for support FTS development. However, research is still needed to address some aspects related to FTS characteristics and software development variables such as number of members, experience level, and risk management.
6. *Task allocation:* the task allocation in the context of FTS involves scheduling the tasks of a project with dependence relationship between tasks to the team members geographically distributed in different time zones. Studies are needed on finding a solution for task scheduling problem.
7. *Project management:* the focus of FTS is to reduce the software development cycle duration. Thus, research is needed to account for the differences between individual and team-level performance, and to capture team process and outcomes. Also, research could assess whether the type of project management and execution can influence the teams' performance.
8. *Time zone management:* FTS teams are separated by distance and time zone differences. The temporal distance that exists between team members is important for FTS development because it allows creating a software development life cycle of the 24 hours. The identification and discussion of the strategies and models for time zone management in FTS development are important to deliver benefits in the software development life cycle duration.
9. *Technologies*: the challenge for software engineering research is to devise tools for FTS implementation that systematically build and exploit the teams' capabilities. For the most part the tools available in this area have been borrowed from related fields.

6. Conclusions

In this paper, we present a systematic mapping study in FTS software development. We have selected 57 papers to address the following research questions: Which FTS studies have been published in the literature? And what empirical support is provided for them? In order to answer these questions, we identified when and where the FTS research papers were published, what research topics and research gaps are addressed in FTS studies, which are the adopted research methods and which countries are involved in FTS research.

Our findings showed that FTS is an active research topic in the software engineering field. We found 32 FTS studies reported in 57 papers. However, over the 21 years since the first FTS study was published, we observe a lack of knowledge available on solutions for FTS practice. The discussion about interpretations of the investigated papers shows the need to better understand FTS development and to provide solutions for its implementation.

The majority of FTS studies adopt the combination of the case study as a research method and interview as a research sub-method. However, the lack of software organizations adopting FTS development makes it difficult to combine theory with practice. We conclude that the state of the practice in FTS is still evolving. We suggest evaluation research for testing FTS feasibility and effectiveness in different software development scenarios such as in agile contexts.

We acknowledge that research gaps cannot be achieved without getting a better understanding of FTS. Our framework considers various research topics and gaps showing the emergent need for research in such topics. Since, FTS is an active topic within academia and it may have been adopted in the software industry in different ways, we acknowledge the importance in building new theories for the area. In addition, the variability of terms used in a similar way is a clear issue for FTS research. Thus, this study will help to focus research efforts on areas of practical importance in FTS and thereby help advance the state of practice in this area.

The results of this study contribute to FTS research in complimentary ways. First, the results from the systematic mapping study provide the academic community a better understanding of the FTS gaps in the area that opens opportunities for future research such as FTS development with agile teams. The increased adoption of agile approaches in the software industry, cloud development and deployment, and micro releases through DevOps models[1], may hold significant implications for FTS. Second, the framework can support researchers and practitioners in the identification of relevant topics and challenges.

In the future we plan to continue this study by concentrating on the identified research gaps and solutions for FTS development. Moreover, we also plan to explore underlying theoretical issues in FTS and collect project case experiences from the software industry.

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[1]DevOps - acronym for Development (Dev) and Operations (Ops) of information technology systems and applications - is a set of practices intended to reduce the time between committing a change to a system and the change being placed into normal production, while ensuring quality. DevOps practices impact processes, products, associated technologies, organizational structures, and business practices [24].

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