Challenges and Solutions in Distributed Software Development Project Management: a Systematic Literature Review

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***Abstract*—This paper presents a systematic literature review of the challenges, best practices, models, and tools in Distributed Software Development (DSD) Project Management. The objective is to collect and systematize reported knowledge in terms of what are the difficulties in managing DSD projects, what are the best practices to overcome these difficulties, and how existing models and tools support these practices. We found 54 works related to DSD project management, published between 1998 and 2009. Using the data systematically extracted from these works, we propose an evidence-based DSD project management improvement model. Our contention is that this model can support practitioners and researchers to better understand the landscape of DSD project challenges and devise more effective solutions to improve project management in a distributed setting.**

Keywords-project management; distributed software development; software engineering; systematic literature review.

I. INTRODUCTION

Management of distributed software development projects has more challenges and difficulties than traditional (co-located) development [9][11]. The main reason cited by researchers and practitioners is that in a distributed development new variables and related challenges are added to the already complex problem of software project management: physical and geographic separation among teams, social and cultural differences among people [7][8], time zone differences, etc. which impact communication and collaboration [2][3], problem solving, trust, and several other factors that influence project success.

While there is increasing recognition amongst practitioners and academics that DSD imposes greater challenges and difficulties for project management, most organizations still manage distributed projects using the same methods, processes, and tools used in traditional projects [2][6][12]. Although [4] presents a systematic review of challenges in DSD, no systematic literature review has been undertaken to bring together the challenges and related solutions in terms of best practices, tools, and models to improve management of distributed software projects.

Therefore, given the importance of effectively managing distributed software development projects, we carried out a systematic literature review of what are the difficulties or challenges in managing DSD projects, what are the best practices to overcome these difficulties, and how existing models and tools support these practices. A systematic literature review aims to evaluate and interpret all available knowledge relevant to a particular research question or topic, by using a rigorous, auditable, and reproducible method. In this work, the guidelines provided by [5] the structure of the presentation of [1] are followed.

This systematic review aimed to answer four research questions:

- *RQ1: What are the challenges in project management of distributed software development?*
- *RQ2: What are the best practices that improve project management of distributed software development?*
- *RQ3: What are the tools used to support project management of distributed software development?*
- *RQ4: What models of distributed software development exists?*

Altogether, 30 challenges, 31 management best practices, 10 models, and 24 tools were collected from 54 works published between 1998 and 2009. The key finding is that the vast majority of the reported studies show only qualitative data about the effect of best practices, models, and tools on solving the challenges of DSD project management. In other words, our findings indicate that strong (quantitative) evidence about the effect of using best practices, models, and tools in DSD projects is still scarce in the literature. This reflects that research in this theme is still in its early stages and requires maturation.

Using the data systematically extracted from these 54 works, we propose an evidence-based DSD project management improvement model. Our contention is that this model can contribute to the DSD field in two complementary ways. On the one hand, to support practitioners in the identification of relevant challenges and definition of mitigating solutions to overcome them by using best practices, tools, and models that have been already tested in experimental and industrial settings. On the other hand, to aid the academic community to better understand the landscape of DSD project challenges and devise experiments to increase the strength of the evidences about the effect of using best practices, models, and tools in DSD, thus increasing the maturity of the area.

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II. METHODS

In this section, the research method of systematic literature review is presented.

A. Research Steps

In accordance to the recommendations of [5], the research was conducted through the following steps:

1) Planning the Review
- Identification of the need for a review (Section I)
- Specifying the research question(s) (Section I)
- Developing a review protocol
- Evaluating the review protocol (carried out by an specialist in systematic review and DSD)

2) Conducting the Review
- Identification of Primary Studies
- Selection of Primary Studies
- Study quality assessment
- Data extraction
- Data synthesis

3) Reporting the Review
- Specifying dissemination mechanisms
- Formatting the main report

B. Search Terms

The search terms are built in three steps. First, the key words of each research questions were classified according to the PICOC (Population, Intervention, Context, Outcome, and Comparison) structure, as recommended by [5]. Second, synonyms for the keywords were defined by consulting specialists in DSD. Third, the search terms were built by joining the synonyms with operator OR and each element of the PICOC structure using the operator AND, and by using wildcards like "*". Adjustments necessary to fit the syntax of the search engines were done in the original search term, and recorded in the protocol document. The example for research question RQ3 is shown below.

1) First Step: PICOC Structure

RQ3: What are the tools used to support project management of distributed software development?
- Population: *Distributed Software Development*
- Intervention: *tools*
- Outcome: *project management*

Context and Comparison are not relevant in this work.

2) Second Step: Synonyms
- Population: "Distributed software development","Global software development"; "Collaborative software development"; "Global software engineering"; "Globally distributed work"; "Collaborative software engineering"; "Distributed development"; "Distributed teams"; "Global software teams"; "Globally distributed development"; "Geographically distributed software development"; "Offshore software development"; Offshoring; Offshore; "Offshore outsourcing"; "Dispersed teams".
- Intervention: "Tool"; "Method"; "Technique"; "Methodology Software"; "Program"; "System".
- Outcome: "Project Management".

3) Third Steps: AND and OR and Wildcards
- Search term or string: ("Distributed software development" OR "Global software development" OR "Collaborative software development" OR "Global software engineering" OR "Globally distributed work" OR "Collaborative software engineering" OR "Distributed development" OR "Distributed teams" OR "Global software teams" OR "Globally distributed development" OR "Geographically distributed software development" OR "Offshore software development" OR Offshoring OR Offshore OR "Offshore outsourcing" OR "Dispersed teams") **AND** (Model* OR Process* OR Framework* OR Method* OR Technique* OR Methodolog* OR Tool* OR Software* OR Program* OR System*) **AND** ("Project Management")

C. Resources Searched

The search was performed in the following databases: (1) IEEEXplore Digital Library; (2) ACM Digital Library; (3) ScienceDirect; (4) EI Compendex; (5) ICGSE 2009 - 4th International Conference on Global Software Engineering (whose papers were not available on the IEEEXplore at the time the initial search as performed).

D. Study Selection Criteria

Primary studies were selected according to the following inclusion and exclusion criteria:

1) Inclusion Criteria
- The study directly answers one of the research questions.
- The study is available for access through the Federal University of Pernambuco online library service.

2) Exclusion Criteria
- Duplicated or repeated studies.
- Opinion pieces, viewpoints or purely anecdotal.
- Studies showing in progress research or incomplete results.

E. Study Selection Process

The selection process was developed in four steps:
- Step 1: Two researchers performed the searches in order to identify **potentially relevant studies**. Then, the selection was based on the titles, excluding those papers which are clearly not relevant.
- Step 2: The two lists resulting from Step 2, one from each researcher, were merged. At this point, disagreements between the researches were resolved by a specialist.
- Step 3: Studies in the resulting list of Step 2 were evaluated by reading abstract and conclusion. Then, by using the study selection criteria, a final list of relevant studies was created.
- Step 4: Studies included in the list of relevant studies were documented using specific forms. Besides, the excluded studies were also documented and the reasons for exclusion were recorded.

F. Study Quality Assessment Criteria

Each study in the list resulting from Step 3 was assessed for its quality using ten criteria (not presented here due to space restrictions). Two researches provided scores for each criterion using a Likert-5 scale, varying from 4 (study fits the criterion completely) to 0 (study does not fit the criterion). Discrepancies above 5% in the final score were discussed and expert opinion was sought whenever necessary to reach an agreement. For a fair comparison across studies, the data was normalized as performed in [1] (TABLE I). Further details on this quality assessment are available at http://www.cin.ufpe.br/~fabio/hase-2010.002.pdf .

G. Data Extraction and Synthesis

JabRef (http://jabref.sourceforge.net/) was used in the data extraction process. Data extraction forms were implemented using JabRef to record information about how the studies answered the research questions. Once data from the studies were recorded, qualitative analysis was carried using constant comparison method [10]. From this analysis, categories of challenges and best practices were created, that are reported in the results section.

III. RESULTS

A. Background

1) Number and Source of Primary Studies

Step 1 (Section II.B) retrieved 1992 studies from the scientific databases listed in Section II.C. After performing the document selection procedure described in Step 3 of Section II.B, 54 relevant articles were selected. The distribution of these articles among the database sources is shown in TABLE II.

2) Temporal View of the Publications

Although the date of publication was not a selection criterion, all selected studies were published between 1998 and 2009, showing the relevance that this theme has recently acquired. Besides, 40 studies (74%) have been published after 2006, which coincides with the startup of new conferences in the theme, including the ICGSE.

TABLE I. QUALITY SCORES OF SELECTED STUDIES

	Poor <26%	Fair 26%-45%	Good 46%-65%	Very Good 66%-85%	Excellent >86%
# of Studies	0	0	9	29	16
%	0%	0%	16,7%	53,7%	29,6%

TABLE II. STUDIES REVIEWED AND VALIDATED

Source	Search Results	Potentially Relevant Studies	Not Relevant	Repeated	Incomplete	Relevant Studies
IEEEXplore	215	51	18	0	5	28
ACM	700	33	21	0	2	10
ScienceDirect	300	11	6	0	0	5
EI Compendex	713	19	9	8	0	2
ICGSE2009	64	41	28	0	4	9
TOTAL	**1992**	**155**	**82**	**8**	**11**	**54**

3) Type of Studies

Out of the 54 primary studies, 22 (41%) are empirical (findings are based on direct evidence or experiment), 20 (37%) are theoretical or conceptual (based on an understanding of the theme from experience or reference to other work), 11 (20%) present industrial reports, and only 1 (2%) is a systematic literature review.

4) Data Sources

Conference proceedings provided 38 studies (70%) and periodicals 16 (30%). Among those from conference proceedings, 20 (52%) are from ICGSE and the remaining 18 (48%) come from 16 different events. Among those from periodicals, 5 (45%) came from IEEE Software, 3 (27%) from Communications of the ACM, 2 (18%) from the International Journal of Project Management, 2 (18%) from IEEE Computer, and the remaining four studies came each one (9%) from the European Management Journal, Information and Software Technology, the Journal of Engineering and Technology Management, and the Journal of Product Innovation Management.

B. Challenges, Best Practices, Models and Tools

This section presents the synthesis of the evidences on challenges of DSD project management and the best practices, tools, and models that are reported as having a positive effect on dealing with those challenges. Citations for the 54 studies included in this review are presented in Further Reading, with the numbers preceded by PS (Primary Study) to distinguish from numbering of the References.

Figure 1. shows the relationships among the research questions. The starting point is the data collected on challenges of project management in a distributed development setting (RQ1) and the best practices used to overcome them (RQ2). Then, tools (RQ3) and models or frameworks (RQ4) that support best practices or directly address the challenges were related to the initial evidences.

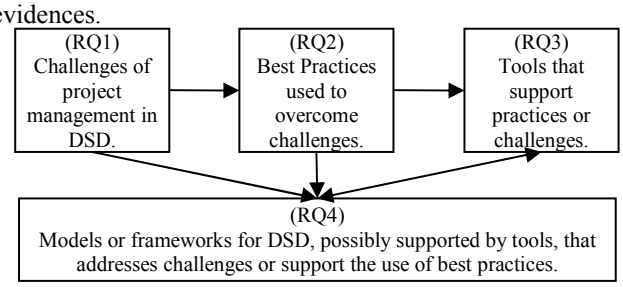

Figure 1. Relationship between the four Research Questions

1) RQ1 – Challenges in project management of DSD

The challenges in the management of DSD projects are summarized in TABLE III. The first column shows the categories of challenges constructed from the data extracted from the evidences that are presented in the second column. The frequencies show the number of occurrences of each category. Each occurrence was given the same weight, thus the frequencies merely reflect how many times a given category was identified in different studies, not how important it may be.

TABLE III. CHALLENGES IN PROJECT MANAGEMENT OF DSD

Challenge (C1-C30)	Evidence (PS1-PS54)
C1. Effective Communication (Frequency: 34)	PS01, PS02, PS05, PS07, PS08, PS09, PS11, PS12, PS13, PS14, PS15, PS17, PS18, PS19, PS20, PS21, PS22, PS23, PS24, PS25, PS26, PS29, PS31, PS32, PS38, PS40, PS41, PS45, PS46, PS47, PS50, PS51, PS52, PS53.
C2. Cultural Differences (Frequency: 31)	PS01, PS02, PS04, PS05, PS07, PS10, PS11, PS12, PS13, PS14, PS19, PS20, PS22, PS23, PS24, PS25, PS26, PS31, PS32, PS33, PS35, PS38, PS41, PS42, PS45, PS46, PS47, PS48, PS49, PS52, PS54.
C3. Coordination (Frequency: 23)	PS02, PS09, PS10, PS11, PS13, PS17, PS18, PS19, PS21, PS24, PS28, PS30, PS31, PS32, PS33, PS36, PS37, PS40, PS41, PS45, PS47, PS51, PS54.
C4. Time Zone Differences (Frequency: 19)	PS01, PS02, PS04, PS05, PS11, PS14, PS19, PS21, PS23, PS24, PS25, PS26, PS31, PS38, PS41, PS45, PS52, PS53, PS54.
C5. Trust (Frequency: 13)	PS01, PS04, PS13, PS19, PS21, PS23, PS25, PS26, PS29, PS42, PS47, PS48, PS50.
C6. Asymmetry in Processes, Policies, and Standards (Frequency: 13)	PS01, PS02, PS03, PS14, PS20, PS25, PS26, PS33, PS38, PS40, PS41, PS42, PS54.
C7. Physical Distance (Frequency: 13)	PS01, PS02, PS11, PS14, PS16, PS19, PS23, PS24, PS31, PS39, PS42, PS45, PS54.
C8. IT Infrastructure (Frequency: 13)	PS01, PS03, PS05, PS13, PS21, PS23, PS24, PS25, PS30, PS40, PS45, PS53.
C9. Different Knowledge levels or Knowledge Transfer (Frequency: 11)	PS02, PS06, PS11, PS13, PS14, PS15, PS31, PS38, PS43, PS47, PS49.
C10. Tracking and Control (Frequency: 10)	PS02, PS04, PS06, PS13, PS19, PS24, PS25, PS32, PS45, PS54.
C11. Cooperation (Frequency: 10)	PS14, PS20, PS21, PS25, PS30, PS40, PS43, PS47, PS51, PS53.
C12. People Mangement/ Conflict Resolution (Frequency: 9)	PS03, PS14, PS15, PS24, PS26, PS35, PS40, PS45, PS49.
C13. Language Barriers (Frequency: 9)	PS03, PS07, PS14, PS20, PS23, PS26, PS33, PS48, PS52.
D14. Task Allocation (Frequency: 7)	PS04, PS06, PS07, PS13, PS18, PS44, PS50.
C15. Identification of Roles and Responsibilities (Frequency: 7)	PS03, PS13, PS14, PS26, PS33, PS40, PS42.
C16. Knowledge Management (Frequency: 6)	PS15, PS17, PS18, PS30, PS34, PS38.
C17. Scope and Change Management (Frequency: 6)	PS07, PS11, PS13, PS25, PS26, PS35.
C18. Overall Visibility (Frequency: 6)	PS09, PS25, PS38, PS40, PS41, PS50.
C19. Differences in Technologies Used (Frequency: 5)	PS02, PS10, PS11, PS26, PS46.
C20. Creating team spirit (Frequency: 5)	PS19, PS21, PS23, PS31, PS54.
C21. Project planning (Frequency: 5)	PS13, PS25, PS33, PS38, PS49.
C22. Quality (Frequency: 5)	PS03, PS07, PS12, PS18, PS35.
C23. Intellectual Property Issues/Confidentiality and Privacy. (Frequency: 4)	PS05, PS20, PS22, PS35.
C24. Different Stakeholders (Frequency: 3)	PS01, PS03, PS05, PS27.
C25. Schedule Management (Frequency: 3)	PS26, PS35, PS41.
C26. Synchronizing Work Between Distributed Sites. (Frequency: 3)	PS01, PS20, PS22.
C27. Different Governments, Laws, Rules and Regulations (Frequency: 2)	PS03, PS31.
C28. Risk Management (Frequency: 2)	PS35, PS40.
C29. Application of an Iterative Agile Process (Frequency: 1)	PS36.
C30. Need of Office Space (Frequency: 1)	PS53.

2) RQ2 – Best Practices that improve project management of DSD

The best practices in the management of DSD projects are summarized in TABLE IV. The first column shows the categories of best practices constructed from the data extracted from the evidences that are presented in the second column. As for the Challenges, the frequencies show the number of occurrences of each category.

TABLE IV. BEST PRACTICES IN THE MANAGEMENT OF DSD PROJECTS

Best Practice (BP1-BP31)	Evidence (PS1-PS54)
BP1. Provision of and training in collaboration and coordinationTools. (Frequency: 10)	PS09, PS11, PS26, PS30, PS32, PS40, PS45, PS46, PS47, PS53.
BP2. Multiple communication modes including support to face-to-face syncronous communication. (Frequency: 8)	PS11, PS17, PS29, PS31, PS46, PS50, PS52, PS53.
BP3. To divide the work into well defined modules and carry out progressive integration. (Frequency: 7)	PS02, PS30, PS31, PS36, PS40, PS41, PS45.
BP4. Training on different cultures/Instil a sense of cultural awareness. (Frequency: 7)	PS24, PS26, PS30, PS32, PS42, PS46, PS47.
BP5.Creation of Communication Protocols. (Frequency: 6)	PS23, PS24, PS32, PS40, PS42, PS47.
BP6. People Management. (Frequency: 6)	PS14, PS30, PS35, PS40, PS43, PS45.
BP7. To promote Informal Interactions. (Frequency: 6)	PS02, PS21, PS23, PS24, PS29, PS31.
BP8. To apply agile practices (SCRUM). (Frequency: 5)	PS10, PS19, PS20, PS29, PS53.
BP9. To deploy knowledge transfer mechanisms. (Frequency: 5)	PS02, PS04, PS14, PS30, PS43.
BP10. To use and maintain common software process among sites. (Frequency: 5)	PS09, PS14, PS20, PS40, PS45.
BP11. Detailed planning. (Frequency: 5)	PS04, PS24, PS31, PS38, PS42.
BP12. To promote visits and exchanges among sites. (Frequency: 5)	PS21, PS31, PS38, PS45, PS52.

BP13. To stimulate Cooperation and Collaboration. (Frequency: 4)	PS21, PS30, PS35, PS53.
BP14. To deploy and use a configuration management system. (Frequency: 4)	PS31, PS35, PS40, PS45.
BP15. Synchronicity : to set up meetings at times reasonable for most teams. (Frequency: 4)	PS02, PS21, PS29, PS46.
BP16. Visibility work progress. (Frequency: 4)	PS02, PS09, PS40, PS41.
BP17. Create teams with complementary skills and cultures. (Frequency: 3)	PS24, PS32, PS46.
BP18.To have clearly defined roles and responsibilities. (Frequency: 3)	PS30, PS40, PS42.
BP19. Secure IT infrastructure: to ensure infrastructure compatibility among geographic locations. (Frequency: 3)	PS30, PS40, PS45.
BP20. Effective policies for confidentiality, copyright protection, and intellectual property. (Frequency: 3)	PS04, PS35, PS40.
BP21. Maintain team involvement and cohesion. (Frequency: 3)	PS21, PS46, PS54.
BP22. To have clear criteria for task allocation. (Frequency: 2)	PS07, PS30.
BP23. Face-to-face kickoff: starting a new project with face-to-face meeting (Frequency: 2)	PS38, PS54.
BP24. Constant Risk Management. (Frequency: 2)	PS35, PS40.
BP25. Schedule management. (Frequency: 2)	PS35, PS41.
BP26. To implement follow up system.	PS30, PS32.
BP27. To maintain common quality standards among sites. (Frequency: 2)	PS04, PS35.
BP28. Wrok synchronization amont sites: to define synchronization points among teams. (Frequency: 2)	PS01, PS22.
BP29. To use a Knowledge Management Systems. (Frequency: 2)	PS22, PS34.
BP30. To secure office space for local teams. (Frequency: 1)	PS53.
BP31. Outsourcing manager is part of two companies. (Frequency: 1)	PS14.

3) RQ3 – Tools used to support project management of DSD

The tools used in the management of DSD projects are summarized in TABLE V. Different from the previous two tables, the first column of TABLE V shows the actual tools reported in the primary studies of the second columns. In this case, the constant comparison method to create categories was not used since the interest was in the actual tools instead of categories.

One important finding is that the majority of the evidences report the use of traditional tools. Only 4 (16%) studies actually propose tools that have specifically designed for DSD. This might indicate that the development of specific tools still require more effort. Another important aspect is that the only evidence in these cases comes from the studies that proposed the use of the tool, indicating that these tools have not been experimented and tested more widely.

4) RQ4 – Models and Frameworks for Distributed Software Development

This section presents the models and framework proposed in the literature to support various distributed software development issues and challenges (TABLE VI).

TABLE V. TOOLS THAT SUPPORT PROJECT MANAGEMENT OF DSD

Tools (T1-T24)		Evidence (PS1-PS54)
TRADITIONAL	T1. E-mail	PS01, PS02, PS07, PS09, PS17, PS20, PS21, PS24, PS25, PS26, PS29, PS32, PS36, PS40, PS50, PS51, PS52.
	T2. Videoconference	PS01, PS02, PS09, PS17, PS22, PS24, PS26, PS29, PS32, PS36, PS40, PS50, PS51, PS52.
	T3. Messenger or chat	PS02, PS09, PS16, PS20, PS21, PS22, PS29, PS32, PS50, PS51, PS52.
	T4. Phone	PS07, PS09, PS21, PS24, PS25, PS32, PS40, PS50, PS52.
	T5. Teleconference	PS01, PS20, PS26, PS31, PS32, PS40, PS41, PS52.
	T6. Wiki	PS09, PS17, PS21, PS29, PS41, PS52, PS53.
	T7. Audio conference	PS01, PS24, PS29, PS51, PS50.
	T8. NetMeeting	PS16, PS21, PS32, PS40.
	T9. Change management system	PS09, PS25, PS36, PS51.
	T10. Virtual whiteboards	PS22, PS24, PS51, PS53.
	T11. Photo gallery	PS21, PS25, PS53.
	T12. Team Intranet websites	PS24, PS40, PS41.
	T13. Monitoring and Management	PS20, PS53.
	T14. Group calendars	PS21, PS24.
	T15. Fax	PS32, PS40.
	T16. Eletronic meeting systems	PS24, PS53.
	T17. PowerPoint presentations	PS26.
	T18. Blog	PS53.
	T19. Nor-real-time databases	PS53.
	T20. Voicemail	PS24.
SPECIFIC	T21. CAMEL	PS15.
	T22. NEXTMOVE	PS37
	T23. TAMRI	PS44.
	T24. TeamSpace	PS08.

TABLE VI. MODELS TO SUPPORT DISTRIBUTED SOFTWARE DEVELOPMENT

Model (M1-M10)	Evidence (PS)
M1. Approach to Offshore Collaboration	PS04
M2. Conceptual Model for Managing an International IS Development Project	PS51
M3. Framework for Supporting Management in Distributed Information Systems Development	PS02
M4. Framework to Enable Coordination in Distributed Software Development	PS11
M5: NEXTMOVE	PS37
M6. Project Management Framework	PS27
M7. Project Management Model	PS39
M8. Process Maturity Framework for Managing Distributed Development	PS30
M9. Solar System	PS09
M10. TAPER	PS45

Similarly to the specific tools presented in the previous section, all models and frameworks are only referenced by one primary study. This also indicates that the models have not been tried by people other than their authors or if they

have been, the evidences about their effect on DSD project management have not yet been published.

In both cases, this weakens the relevance of the evidences due to the potential bias that the authors of the tools and models may have when reporting their results. An important conclusion is that empirical studies carried out outsiders are necessary to construct more reliable evidence about these tools and models.

C. DSD Project Management Improvement Model

In this section, a model is proposed to guide improvements in the management of DSD projects. This model is structure in two levels. At the Theory Building level, using evidences from scientific and industrial experimentation, the model is constantly refined and a theory of DSD project management can gradually and cooperatively be built. At the Experimentation level, theoretical constructs and cause-effect relationships defined in the model are used to seek for an effect on industrial or academic problems. Then, the resulting effects of experiments on real problems are used as further evidence to refine the model in the Theory Building level.

To construct the Model, evidences related to Challenges, Best Practices, Tools, and Models (presented separately in Section B) have been combined in TABLES VII-XI. Phases of the Model are shown in Figure 2. and detailed below.

1) Phase 1: Observe

Observe the current situation of DSD project management looking for problems. Find answers to the question "What is wrong with current situation?". Use the Challenges in TABLE III to guide the observation. Create a list of Challenges and problems relevant to the current situation. Order the findings according to the order of related challenges, given by the frequencies in TABLE III.

2) Phase 2: Theorize (1, 2, and 3)

Create a potential solution for each problem or challenge identified in the *Observe* phase. Use the model components to related Challenges and Tools (T) (TABLE VII), Challenges and Models (TABLE VIII), Challenges and Best Practices (BP) (TABLE IX), BP and Tools (TABLE X), and BP and Models (TABLE XI). At this point, the hypotheses are that the deployment and use of selected BP, Tools, and Models (treatments) will have a positive effect on the identified problems. Quantify (if possible) the desired effect of each treatment.

3) Phase 3: Design

Plan the application of the treatments identified in Phase 2 through (a set of) empirical tests of the hypotheses generated in the previous phase.

4) Phase 4: Experiment

Apply the treatments on the current situation and collect data about their effect on the problems.

5) Phase 5: Evaluate

Assess the effectiveness of the treatments by evaluating their effect on the original problem situation. Feedback the results to both the *Observe* and the *Collect* phases. The improvement cycle can continue by addressing new challenges and problems.

6) Phase 6: Collect

Collect evidence from empirical studies that relate BP, Tools, and Models to problems and challenges in DSD project management. The systematic review protocol can be used to guide the collection of evidence. The results of experiments of Phase 5 also provide input to this phase.

7) Phase 7: Refine

Use the new evidences from empirical studies to refine the model by modifying TABLES III-XI according to the empirical results.

TABLE VII. CHALLENGES AND TOOLS

Challenge	Tool	Evidence (PS1-PS54)
C1	T1	PS01, PS02, PS07, PS09, PS17, PS20, PS21, PS24, PS26, PS29, PS32, PS36, PS40, PS50, PS51, PS52.
	T2	PS01, PS02, PS09, PS17, PS24, PS26, PS29, PS32, PS36, PS40, PS50, PS51, PS52.
	T3	PS02, PS09, PS16, PS20, PS21, PS51, PS52.
	T4	PS07, PS09, PS21, PS24, PS32, PS40, PS50, PS52.
	T5	PS01, PS20, PS26, PS31, PS32, PS40, PS41, PS52.
	T6	PS09, PS17, PS29, PS41, PS52, PS53.
	T7	PS01, PS24, PS29, PS51, PS50.
	T8	PS16, PS21, PS32, PS40.
	T10	PS24, PS51, PS53.
	T12	PS24, PS40, PS41.
	T13	PS20, PS53.
	T14	PS21, PS24.
	T15	PS32, PS40.
	T16	PS24, PS53.
	T17	PS26.
	T18	PS53.
	T19	PS53.
	T20	PS24.
	T21	PS15
	T22	PS37
	T24	PS08
C2	T6	PS21
C3	T6	PS21
	T14	PS21
C5	T6	PS21
	T11	PS25
C11	T1	PS25
	T2	PS22
	T3	PS22
	T4	PS25
	T9	PS25
	T10	PS22
	T11	PS25
C12	T21	PS15
C13	T1	PS52
C14	T23	PS44
C17	T9	PS09, PS25, PS36, PS51

The vast majority of the studies present evidences of the use of tools to deal with the communication challenges in DSD. It is important to notices that only a small percentage of the Challenges are addressed by the use of supporting tools in the studies (9/30%). Furthermore, none of the studies show quantifiable and strong evidence about the effect of the use of the tool on the related challenged.

TABLE VIII. CHALLENGES AND MODELS

Challenge	Models	Evidence (PS1-PS54)	Challenge	Models	Evidence (PS1-PS54)
C1	M1	PS04	C9	M1	PS04
	M3	PS02	C10	M3	PS02
	M6	PS27	C11	M8	PS30
	M9	PS09	C12	M2	PS51
C3	M3	PS02		M9	PS09
	M4	PS11	C14	M5	PS37
	M9	PS09	C15	M8	PS30
C5	M10	PS45	C18	M9	PS09
C6	M1	PS04	C21	M7	PS39
C8	M2	PS51			

TABLE IX. CHALLENGES AND BEST PRACTICES

Challenge	Best Practice	Evidence (PS1-PS54)
C1	BP1	PS02, PS04, PS11, PS17, PS30, PS31, PS46 PS50, PS52, PS53
	BP2	PS09,PS11,PS26, EP40, PS45, PS46, PS47, PS50
	BP5	PS31, PS38
	BP7	PS10, PS20, PS29, PS53
	BP8	PS23, PS24, PS32, PS40, PS47
	BP9	PS09
	BP12	PS20, PS45
	BP14	PS02, PS31
	BP15	PS46, PS53
	BP23	PS38
	BP31	PS14
C2	BP4	PS24, PS26, PS30, PS32, PS42, PS46, PS47
	BP5	PS45, PS52
	BP16	PS24, PS26, PS32, PS46
	BP31	PS14
C3	BP3	PS02, PS30, PS31, PS36, PS40, PS41, PS45
	BP7	PS19, PS10, PS37
	BP12	PS45
C4	BP15	PS02, PS21, PS29, PS46
C5	BP2	PS50
	BP14	PS21, PS24, PS29
	BP5	PS21, PS23, PS31
C6	BP12	PS09, PS14, PS40
	BP31	PS14
C7	BP30	PS53
C8	BP2	PS46, PS53
	BP9	PS30, PS40, PS45
C9	BP11	PS02, PS04, PS30, PS43
	BP31	PS14
C10	BP12	PS45
	BP26	PS30, PS32
C11	BP2	PS21
	BP5	PS53
	BP10	PS21, PS30, PS35, PS40, PS53
C12	BP6	PS14, PS30, PS35, PS40, PS43 PS45
	BP31	PS14
C13	BP1	PS52
C14	BP3	PS30
	BP17	PS30
	BP22	PS07, PS30
C15	BP17	PS30, PS40, PS42
	BP31	PS14
C16	BP29	PS22, PS34
C17	BP19	PS31, PS35, PS40
	BP26	PS30, PS32
C18	BP9	PS50
	BP12	PS09
	BP20	PS02, PS09, PS40, PS41
	BP17	PS40
C20	BP21	PS21, PS46, PS54
	BP23	PS38, PS54
C21	BP13	PS04, PS24, PS38, PS42
C22	BP17	PS35
	BP27	PS04, PS35
C23	BP9	PS45
	BP18	PS04, PS35, PS43, PS45
C25	BP25	PS35, PS41
C26	BP28	PS01, PS22
C27	BP13	PS31
C28	BP24	PS35, PS40
C30	BP30	PS53

TABLE X. BEST PRACTICES AND TOOLS

Best Practice	Tool	Evidence (PS1-PS54)
BP1	T1	PS02, PS17, PS50, PS52.
	T2	PS02, PS17, PS50, PS52.
	T3	PS02, PS50, PS52.
	T4	PS50, PS52.
	T5	PS31, PS52.
	T6	PS17, PS52, PS53.
	T7	PS50
	T10	PS53
	T13	PS53
	T16	PS53
	T18	PS53
	T19	PS53
BP2	T1	PS09, PS26, PS32, PS40, PS50
	T2	PS09, PS26, PS32, PS40, PS50
	T3	PS09, PS32, PS50
	T4	PS09, PS40, PS50
	T5	PS26, PS32, PS40
	T6	PS09, PS53
	T7	PS50
	T8	PS32, PS40
	T9	PS09
	T10	PS53
	T11	PS53
	T12	PS40
	T13	PS53
	T15	PS32, PS40
	T16	PS53
	T17	PS26
	T18	PS53
	T19	PS53
BP15	T3	PS21
	T4	PS21
	T24	PS08
BP22	T23	PS44

TABLE XI. BEST PRACTICES AND MODELS

Best Practice	Model	Evidence (PS1-PS54)	Best Practice	Model	Evidence (PS1-PS54)
BP1	M2	PS51	BP12	M1	PS04
BP3	M8	PS30		M2	PS51
BP6	M9	PS09		M9	PS09
BP9	M2	PS51	BP20	M9	PS09
BP10	M8	PS30	BP22	M5	PS37
BP11	M1	PS04	BP26	M1	PS04
			BP29	M8	PS30

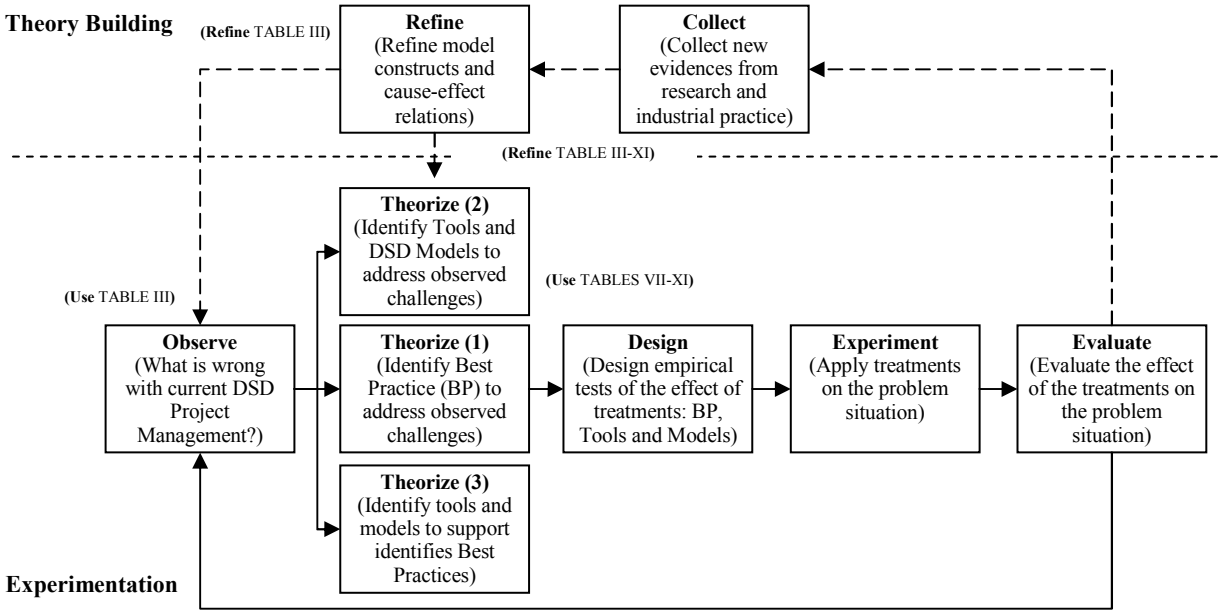

Figure 2. DSD Project Management Improvement Model.

IV. FINAL CONSIDERATIONS

A. Discussion about the Results

The first five Challenges in TABLE III appeared in 120 evidences (45%) out or a total of 266 for all 30 Challenges. This indicates the importance that the primary studies give for the issues of communication, cultural differences, coordination, time zone differences, and trust. The uses of Best Practices are also concentrated to address the problems related to the five first Challenges, as can be seen from TABLE IX. Therefore, these five Challenges are strong candidates to receive attention from researchers and practitioners in DSD. Consistently, the vast majority of the evidences (91/82%) of tool applications are to overcome problems related to communication. Besides, 21 tools (88%) of the total of 24 described in the studies are related to communication support, including 3 out of the 4 specific tools. The support provided by tools to the deployment of Best Practices is weak. Only 4 (12%) of the practices have tool support: 3 of them are related to communication, and 1 to task allocation (an specific tool).

Overall, most solutions in terms of Best Practices, Tools, and Models are provided to overcome the communication challenge in DSD. However, the evidences about Challenges show that emphasis should also be given to cultural differences, coordination, time zone differences, and trust, among others.

B. Limitations and Threats to Validity

One of the strengths of the DSD Project Management Improvement Model is that it is based on existing industrial and scientific evidences. Since these evidences were found in papers from quality journals, periodicals, conferences, etc. it is expected that they have been assessed for validity threats. However, the model inherits the threats to validity of the studies from which the evidences were collected. To overcome this unavoidable weakness, primary studies must be carried out to test the model.

An analysis of the geographical distribution of the empirical studies and the industrial reports was not conducted, because most studies do not provide contextual information about the place where the studies have been carried out. Therefore, it is not possible to know whether or not the studies concentrate in certain regions or countries. This poses a threat to external validity, since it is not possible to know if the results represent all major software producers around the globe. Due to time and budget restrictions, the search did not consider some databases that are suggested in [5]: SpringerLink, Wiley InterScience, InspecDirect, Scirus e Scopus. Although this may represent a limitation and a threat to validity, the main conferences of the area and journals have been searched, reducing the problem. Besides, the review protocol can be used to extend the results by using those and other databases.

C. Further Research

The limitations discussed above offer clear paths to further research. Practical uses of the model, through the development of case-studies or action research in industrial settings are necessary both to test the model and also to increase the number of (stronger) evidences about the use of best practices, tools, and models in DSD project management.

The model can also be refined by increasing the number of primary studies analyzed in the systematic review. Using the protocol, other researchers can independently replicate the study and compare the results.

It is common in qualitative analysis to perform member checking as a form of verification of the accuracy of the evidence extraction and synthesis. An interesting project would be to interview (using online tools) the authors of the primary studies to collect their assessment about the synthesis carried out from their studies.

D. Conclusions

The results and findings of this research suggest an increasing awareness of challenges of DSD project management since 2006, as compared to previous years. The majority of the studies are not empirical, i.e. findings based on direct evidence or experiment. Furthermore, only 20% are reports from industrial experience. It is clear from these findings that although the number of studies is increasing, there is still the need for more empirical research to create stronger and quantifiable evidences of the effect of best practices, tools, and models on DSD.

The results of this research contributed to DSD in complimentary ways. First, the results from the systematic review provide to the academic community a better understanding of the landscape of DSD challenges and show gaps in area that opens opportunities for future research Second, the DSD Project Management Improvement Model can support practitioners and researchers in the identification of relevant challenges and definition of mitigating solutions by using best practices, tools, and models that have been already tested in experimental and industrial settings.

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