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Managing Risks in Distributed Software Projects: An Integrative Framework

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Abstract—Software projects are increasingly geographically distributed with limited face-to-face interaction between participants. These projects face particular challenges that need careful managerial attention. While risk management has been adopted with success to address other challenges within software development, there are currently no frameworks available for managing risks related to geographical distribution. On this background, we systematically review the literature on geographically distributed software projects. Based on the review, we synthesize what we know about risks and risk resolution techniques into an integrative framework for managing risks in distributed contexts. Subsequent implementation of a Web-based tool helped us refine the framework based on empirical evaluation of its practical usefulness. We conclude by discussing implications for both research and practice.

Index Terms—Communication and collaboration, distributed software projects, risk management.

I. INTRODUCTION

GLOBAL competition, increased need for flexibility, access to global resources, and substantial financial gains drive companies to engage in geographically distributed software projects (GDSPs) [37], [91]. Moreover, as electronic communication infrastructures are now readily available, geographically distributed projects have become increasingly feasible to organize and manage [97], [101]. However, these projects face numerous management challenges that are inherent to their distributed nature, e.g., limited social interaction [22], [35], [37], [87], language barriers [22], [88], [100], and time zone differences [12], [16], [25], [47], [100]. While the growth in GDSPs has attracted increasing attention in the literature, there is still considerable variation in the terms used, including virtual teams [88], global virtual teams [41], virtual work groups [99], virtual organizations [59], distributed projects [25], and geographically distributed development teams [28]. In this paper, we focus on GDSPs that “consist of geographically dispersed people working interdependently with shared purpose across space, time, and organizational boundaries and using technology to communicate and collaborate” [99].

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A portfolio of approaches to alleviate specific challenges in GDSPs has been proposed, e.g., dialogue technique [105], list of best practices [5], [24], and a person–environment fit model [103]. These contributions are valuable, but they do not constitute a comprehensive approach to effectively manage the challenges in GDSPs [25], [91]. Moreover, while risk management has been applied successfully in collocated software development [39], [67] the resulting approaches fail to address the unique communicative and collaborative challenges that distinguish GDSPs from traditional software projects [37]. This research was therefore guided by the overall objective to integrate existing knowledge into a practically useful framework for managing risks inherent in GDSPs. In order to do this, we first reviewed the literature to identify and conceptualize the specific risks inherent in GDSPs and to identify and conceptualize the available resolution techniques [67]. Second, we integrated these insights into a framework for applying risk resolution techniques to risks, implemented a tool for practical use of the framework, and refined the framework based on empirical evaluation of its practical usefulness.

The basic principles of risk management seek to generalize patterns of relations between organizational contexts (in the form of risk areas and underlying risk factors) and use of technologies (in the form of resolution techniques) in ways that support human action [67]. A software risk denotes an aspect of a development task, process, or environment, which, if ignored, increases the likelihood of project failure [67]. Practitioners can assess the degree of risk either quantitatively as the probability of unsatisfactory events multiplied by the loss associated with their outcome, or qualitatively by referring to the uncertainty surrounding the project and the magnitude of potential loss associated with project failure [4]. Risk management helps practitioners assess problematic aspects of a project, emphasizes potential causes of failure, helps link potential threats to possible actions, and facilitates a shared perception of a project among its participants [66], [67]. Risk frameworks and associated tools have previously been successfully developed to identify, analyze, and tackle project portfolio risks [23], [75], software development risks [4], [7], [14], [21], [27], [50], [79], [83], [95], software requirements risks [11], [18], [72], software process improvement risks [39], and implementation risks [3], [48], [57], [63], [65].

Our research draws upon a systematic review of the literature on GDSPs (Section II); synthesizes conceptualizations of risks (Section III) and resolution techniques (Section IV) and integrates these into a framework and related tool for managing risks in distributed contexts (Section V); and finally, documents how the framework and tool were refined based on evaluations of their practical usefulness (Section VI). We conclude by

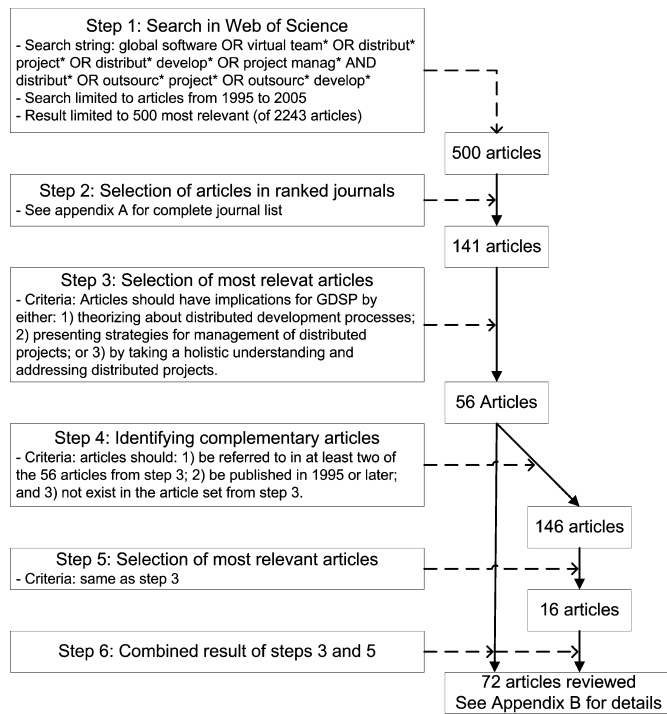


Fig. 1. Literature identification.

discussing the contribution of this research and its implications for theory and practice (Section VII).

II. LITERATURE REVIEW

The primary goal of a literature review is to achieve a complete result focused on concepts [113]. Thus, the two most important tasks are to decide how to identify the relevant literature and how to conceptually structure the analysis [114].

A. Identifying the Literature

As our field of interest was managerial challenges in GDSPs, we chose a wide range of management information systems and management research journals as the primary sources of information. This was based on the assumption that many of the challenges faced by managers of GDSPs are similar to the ones encountered within other industries involved in distributed projects.

Inspired by Webster and Watson [113], we adopted a rigorous approach to identify relevant articles in leading journals. From the identified set of articles, we searched backward by following the used references. This approach was combined with Weill and Olson's [114] suggestion to use structured critique to further steer the selection of articles. Our combined approach is summarized in Fig. 1.

In the first step, we searched for relevant articles in the Web of Science article database. The search was limited to articles published in 1995 or later. Even though GDSPs is not a new phenomenon, it was only with the development of communication and collaboration technology during the 1990s that distributed development was made feasible for entire projects [116]. Based on this, we initially considered GDSP research prior to 1995 to be of lesser interest. In the second step, the resulting set of arti-

cles was limited to include the 500 most relevant according to the Web of Science analysis tool [107]. This set of articles was further restricted to include only those published in rated journals (see Appendix A). The list of rated journals was a result of a thorough examination of studies of journals in our two areas of research: management information systems [45], [62], [92], [115] and management [29], [33], [43]. The resulting articles of these first two steps were evaluated in the third step based on a detailed examination of abstracts. Articles of little or peripheral interest were excluded from the set. To ensure that key articles in our area of research were included in the final set, the fourth step went backward through the cited references of all articles included by the third step. Articles referenced more than once were evaluated using the third step, exempting the rated journal list, since we considered referencing an acceptable quality indicator in itself. The final set of articles for the review is listed in Appendix B.

B. Structuring the Review

The first part of the review was identification of risks most threatening to distributed projects (Section III). According to Boehm [7], risk areas consist of a number of related risk factors, which together possess a threat to the project's success. Thus, risk areas represent categories of risk factors, where the joint assessment of risk factors indicates whether the risk area might become a problem for a project. We adopted a systematic method to synthesize risk areas: we found inspiration in the categories of risk areas used in key articles with an overall perspective on GDSPs; used Leavitt's [60] model as suggested by Lyytinen *et al.* [67] to provide clear foci for a distinct set of risk areas; aggregated a complete list of risk factors identified in the literature and categorized them according to the proposed risk areas; and finally, provided questions and criteria to offer precise definitions of each risk factor.

The second part of the review focused on identifying and categorizing resolution techniques that address risks through managerial intervention (Section IV). As we found no independent categorization of resolution techniques in the reviewed GDSP literature, we looked for inspiration in the software risk management literature. McFarlan [75] presents a generic software risk management framework that has proven its worth time and again over the past 25 years. McFarlan [75] uses four categories of resolution techniques centered on basic project management disciplines and with a particular focus on integration. As integration is a major challenge in managing GDSPs, we adapted McFarlan's framework to help structure the available resolution techniques.

McFarlan's [75] categories are internal integration, consisting of techniques to support coordination and communication internally in the project group; external integration, consisting of techniques to support coordination and communication with external stakeholders; formal planning, consisting of techniques to support planning; and finally, formal control, consisting of techniques to ensure that the formal planning stays on track and is continuously updated in relation to project practices. The literature on GDSPs is less concerned with the challenges of internal

TABLE I
CATEGORIES OF RESOLUTION TECHNIQUES IN GDSP ADAPTED FROM MCFARLAN [75]

Category	Definition
Planning	Techniques that help plan projects to be effectively executed in distributed contexts.
Control	Techniques that facilitate tracking progress and help manage discrepancies in relation to plans in distributed contexts.
Social integration	Techniques that integrate participants and help manage cultural differences across sites in distributed contexts.
Technical integration	Techniques that increase connectivity and technical compatibility across sites in distributed contexts.

and external integration. Instead, there is considerable focus on how communication and collaboration efforts can be supported by various forms of information and communication technology. Also, social integration is generally considered a key challenge because the presence of several cultures in GDSPs creates an environment significantly different from that of collocated projects. Furthermore, recent research has pointed out control as not only being formal but also informal in GDSPs [15], [54]. On that background, we chose to adapt McFarlan's [75] concepts to the following resolution technique categories: planning, control, social integration, and technical integration. Table I provides definitions of these categories.

III. CONCEPTUALIZING RISKS

In the following, we synthesize risk areas across key GDSP articles supported by Leavitt's organizational model [60], [67]. Subsequently, we characterize each risk area and the risk factors it consists of with references to the reviewed articles.

A. Synthesizing Risks

Leavitt's [60] organization model was developed to synthesize the primary dimensions and dynamics of organizations. According to Lyytinen *et al.* [67], it applies well to define risk in software development into distinct areas: task covers the results, products, approaches, and goals of the software project; structure represents the project organization and institutional setting; actors consist of users, managers, developers, and other key stakeholders; and finally, technology consists of development methods and tools and of the hardware and software platforms for the resulting software.

Based on its merits in defining the foci of different risk areas in software development, we used Leavitt's model to propose distinct risk areas based on key GDSP articles. In addition, we aggregated a complete list of risk factors from the reviewed literature and categorized them according to the proposed risk areas. Table II presents the resulting synthesis of risk areas and related risk factors. The first five columns describe the risk categories found in other key articles. These are related to the proposed risk areas in the second last column. A gray cell denotes that the article does not cover that proposed area. The last column defines the focus of each proposed risk area in relation to Leavitt's four dimensions.

Table II documents in this way: (1) how the proposed conceptualization of risk areas synthesizes key articles in the GDSP

literature; (2) how the proposed risk areas represent a balanced view and have distinct foci following Leavitt [60]; and (3) how the complete list of risk factors aggregated from the literature further define each risk area. Elaborate definitions of the questions and criteria needed to assess each risk factor are provided in Table III. These definitions and the foci of risk areas in Table II summarize how the literature has been synthesized into distinct risk areas and related risk factors. The following subsections characterize each risk area and the risk factors it consists of, with references to the reviewed articles.

B. Task Distribution

As in traditional software development, the task represents a possible risk in GDSPs, but for slightly different reasons. When the overall project task is divided and distributed across several sites, task uncertainty emerges, because participants may lack information about the task, its purpose [52], [99], and their own contribution to the overall task [24], [28], [36]. Task uncertainty represents lack of information needed to develop the software [31], [71], [76], and it can result in slow change coordination [36] and process and relational conflicts [99]. Task equivocality, in contrast, represents how well participants understand the specification of the task. For GDSPs, in particular, it is important whether the task is routine or nonroutine and how it relates to the experiences of the project team. High equivocality increases coordination and communication needs [6], [116] and demands on interaction media [99]. Finally, as the task is always distributed in GDSPs, high task coupling between task segments increases the need for intersite communication, coordination, and integration, and it can lead to lower level of performance as well as increase the number of failures [12], [24], [35], [37], [99], [100].

C. Knowledge Management

Knowledge management refers to how projects create, capture, and integrate knowledge about the project task, including goals, problems, possible solutions, and approaches. When GDSP participants lack face-to-face interaction [5], [68], knowledge creation is limited within the organization [68]. This may lead to problems in creating collaboration know-how [17], [68] and domain knowledge [5]. Also, knowledge capture may be limited in GDSPs due to factors such as changing relations and roles across the organization [10], properties of electronic communication media [101], and lacking knowledge of different

TABLE II
SYNTHESIS OF RISK AREAS

Sakthivel [99]	Powell et al. [91]	Townsend et al. [108]	Herbsleb and Moitra [37]	Bell and Kozlowski [6]	Proposed risk areas	Focus [60, 67]
-Task coupling -System Characteristics	-Task-Technology-Structure Fit	-Changing Variety of Assignments and tasks	-Strategic Issues	-Team Task Complexity and Workflow	Task Distribution - Task Uncertainty - Task Equivocality - Task Coupling	Task
	-Training		-Knowledge Management	-Information, Data, and Personal Communication	Knowledge Management - Knowledge Creation - Knowledge Capture - Knowledge Integration	
-Place and Type of Offshore Facility	-Design -Coordination	-Different Geographic Locations		-Spatial Distance -Time Zone Distribution	Geographical Distribution - Spatial Distribution - Temporal Distribution - Goal Distribution	Structure
-Systems Development Processes -Management of Virtual Projects	-Training -Coordination	-Structural Resistance	-Strategic Issues -Project and Process Management Issues	-Team Members' Roles	Collaboration Structure - Collaboration Capability - Coordination Mechanisms - Process Alignment	
-Cultural differences	-Culture	-Cultural Differences	-Cultural Issues	-Spatial Distance	Cultural Distribution - Language Barriers - Work Culture - Cultural Bias	Actor
-Group cohesion	-Trust -Relationship Building -Cohesion	-Trust and Cohesion Issues			Stakeholder Relations - Stakeholder Commitment - Mutual Trust - Relationship Building	
-Interaction Media	-Communication		-Inadequate Communication	-Information, Data, and Personal Communication	Communication Infrastructure - Personal Communication - Interaction Media - Teleconference Management	Technology
-Interaction Media	-Technical	-Tele- and Information Technologies -Technophobia	-Technical Issues	-Information, Data, and Personal Communication	Technology Setup - Network Capability - Tool Compatibility - Configuration Management	

sites [40]. This results in reduced capability to discover defects in the developed software [40] or loss of knowledge about options or specific problem solutions [10]. Knowledge capture is especially important when dissolving the project since it may be difficult to subsequently locate a person who possesses the needed knowledge. Moreover, in GDSPs, changing or unclear organizational structures may lead to limited knowledge integration and sharing [1], [10], [37]. Knowledge sharing may be limited across sites due to noncoherent political agendas, and it may complicate prioritizing assignments appropriately or reduce reuse in software development [37].

D. Geographical Distribution

Distribution of activities in a GDSP occurs along three dimensions: space, time, and goals. Spatial distribution complicates the project manager's ability to monitor participants and progress, increases travel budgets, limits face-to-face interaction, and weakens social relations [5], [6], [20], [25], [100]. Temporal distribution increases the complexity of planning and coordination activities, makes multisite virtual meetings hard to plan [12], [16], [25], [47], causes unproductive waits, delays feedback, and complicates simple things like time referencing and time settings [100]. Besides differences in space and time, goal distribution can potentially lead to conflicts related to task interpretation, process principles, and problem resolution approaches [38] and result in site wars and low perfor-

mance [38], [77], [86]. Goal distribution is more likely in GDSPs because of faulty transfer of information [38] and focus on own site performance.

E. Collaboration Structure

Collaboration is a relatively broad area that covers risks arising when collaboration structures do not fit the distributed context. Collaboration capability describes the project participants' understanding and appreciation of differences in competencies [10], [30] and their ability to effectively use technology to gather and share information across geographical and functional distances [20], [91]. This is often problematic in GDSPs as participants have limited understanding of other project participants' competencies [91], [97], [100]. GDSPs are often characterized by more horizontal organizational structures [10], and flexibility concerning roles and assignments is, therefore, an important quality [108]. Poor fit between project participants and project organization can lead to conflicts, communication problems, and unused potential [103], [104]. Additionally, it may be difficult to establish effective coordination mechanisms in GDSPs, overcoming challenges such as lacking face-to-face interaction [100], problematic task coupling [12], [94], [99], different time zones, local holidays [100], weak social networks [36], and unclear lines of communication [35], [74]. Problems can be exacerbated by weak alignment of coordination mechanisms between sites or by uncritically transferring

TABLE III
DEFINITION OF RISK FACTORS

Risk Area	Risk Factor	Risk Question	Low Risk	Medium Risk	High Risk
Task Distribution	Task Uncertainty	Do participant posses the knowledge and capabilities needed?	Participants know the task and it fits well with their capabilities.	Participants have reasonable task knowledge and their capabilities cover most challenges.	There are serious gaps in the participants' task knowledge and required capabilities.
	Task Equivocality	Do participants understand the specification of the task?	The task is well specified and understood by participants.	Most aspects of the specification are clear and the task is understood by key participants.	The specification lacks clarity on major points and many participants have limited task understanding.
	Task Coupling	Is the task divided into distinct sub-tasks across sites?	There is minor need to coordinate development work across sites.	There is some need to coordinate development work across sites.	There is major need to coordinate development work across sites.
Knowledge Management	Knowledge Creation	How is task knowledge created across sites?	All sites contribute well to creation of required task knowledge.	Most sites contribute reasonably well to creation of required task knowledge.	There are major problems related to creation of required task knowledge.
	Knowledge Capture	How is task knowledge captured across sites?	Task knowledge is captured effectively across sites.	Task knowledge is with some exceptions captured effectively across sites.	There are major problems related to capturing task knowledge across sites.
	Knowledge Integration	How is task knowledge integrated and shared across sites?	Task knowledge is integrated and shared well across sites.	Task knowledge is with some exceptions well integrated and shared across sites.	Task knowledge integration and sharing across sites is limited.
Geographical Distribution	Spatial Distribution	How many sites are involved and what is the distance between them?	There are few sites collaborating over limited distance.	There are several sites collaborating over some distance.	There are many sites collaborating over considerable distance.
	Temporal Distribution	How do time-zone differences impact development work?	Time-zone differences cause no or only minor problems.	Time-zone differences require some ad-hoc coordination across sites.	Time-zone differences cause major problems and require constant attention across sites.
	Goal Distribution	How diverse are goals across sites?	Participants share major goals across sites.	There is some variation in goals across sites.	There are major goal conflicts across sites.
Collaboration Structure	Collaboration Capability	Can participants collaborate across sites?	Participants collaborate across sites as needed.	In most cases, participants collaborate across sites as needed.	Breakdowns in collaboration across sites are common.
	Coordination Mechanisms	Are coordination mechanisms appropriate across sites?	Coordination mechanisms are shared across sites and well adapted to the distributed context.	Coordination mechanisms are shared by most participants and reasonably well adapted to the distributed context.	Coordination mechanisms are not shared across sites and poorly adapted to the distributed context.
	Process Alignment	Are software processes aligned across sites?	Software processes (including methods, templates, and guidelines) are shared across sites.	Software processes (including methods, templates, and guidelines) vary, but are reasonably well aligned across sites.	Software processes (including methods, templates, and guidelines) are different across sites.
Cultural Distribution	Language Barriers	Do language and communication norms vary across sites?	Participants share language and communication norms across sites.	Participants use a common language with minor differences in communication norms.	Participants do not share a common language and have different communication norms.
	Work Culture	Does work culture differ between sites?	Participants share work culture (including authority and team behavior) across sites.	Participants understand variations in work culture (including authority and team behavior) across sites.	Participants do not understand variations in work culture (including authority and team behavior) across sites.
	Cultural Bias	Does cultural bias impact communication and cooperation across sites?	There are no major variations in cultural values across sites.	Participants communicate and collaborate based on appreciation of cultural variations across sites.	Participants lack knowledge of variations in cultural values across sites.

TABLE III
CONTINUED

Stakeholder Relations	Stakeholder Commitment	Are stakeholders committed to the project?	Key stakeholders are committed and share a common project identity across sites.	Most stakeholders are committed to the project and know about its distributed organization.	Stakeholder commitment varies and there is a lack of shared project identity.
	Mutual Trust	Is there trust between stakeholders across sites?	There is appropriate mutual trust across sites.	There are instances of insufficient trust across sites.	Stakeholders do not trust each other across sites.
	Relationship Building	Can the project integrate stakeholders across sites?	Existing and new stakeholders are well integrated across sites.	Existing and new stakeholders are mostly integrated well across sites.	There are several cases of stakeholders not being well integrated.
Communication Infrastructure	Personal Communication	What is the level of personal communication and social interaction across sites?	The level of personal communication and social interaction across sites is appropriate.	There is some personal communication and social interaction across sites.	Personal communication and social interaction across sites is limited.
	Interaction Media	How is communication across sites supported by media?	Communication needs across sites are well supported by media.	Communication across sites is for many purposes well supported by media.	There are severe shortcomings in media support of communication across sites.
	Teleconference Management	How is teleconferencing managed across sites?	Teleconferencing is used appropriately and managed effectively across sites.	Teleconferencing is used to some extent across sites and reasonably well managed.	There is limited use of teleconferencing across sites and they are not managed well.
Technology Setup	Network Capability	Are communication networks reliable?	Networks are not causing delays in development work and communication.	Networks are causing some delays in development work and communication.	Networks are causing serious delays in development work and communication.
	Tool Compatibility	Are tools compatible across sites?	There are no compatibility issues between tools across sites.	Compatibility issues between tools create some collaboration barriers across sites.	Compatibility issues between tools create serious collaboration barriers across sites.
	Configuration Management	How are configurations managed across sites?	There is appropriate configuration management across sites.	Configuration management is with some exceptions appropriate across sites.	There is limited configuration management across sites.

nonapplicable coordination mechanisms from collocated projects to GDSPs [91]. Process alignment in terms of traditions, development methods, and emphasis on user involvement will often differentiate between sites, possibly resulting in incompatibility and conflicts [5], [24], [25], [56], [99], [100].

F. Cultural Distribution

When projects are geographically distributed, a number of cultural problems may arise since participants do not necessarily share the same language, traditions, or organizational culture [80], [93], [106]. Language barriers arise in cross national projects when sites and participants do not share a common language [12], [16], [22], [24], [37], [56], [88], [91], [93], [100] or norms of communication [22], [24], [37], [47], [91], [100], [108] resulting in misinterpretations and un conveyed information [22], [88], [100]. Differences in work culture may render difficulties in a GDSP [22] when sites are different in terms of team behavior [22], balancing of collectivism and individualism, perception of authority and hierarchy [37], [56], [88], planning, punctuality [37], and organizational culture [12], [16]. This may lead to decreased conflict handling capabilities and

lower efficiency [78], [85], or even paralyze the GDSP [22]. Cultural bias occurs when project participants consider their norms and values as universal and neglect to reflect on to what extent values, norms, and biases are founded in their own cultural background [22], [104]. Cultural bias may lead to erroneous decisions [22] and insecurity about other participants' qualifications [5], and it can have a devastating impact on communication and collaboration efforts [47], [88].

G. Stakeholder Relations

When projects are distributed, it naturally becomes difficult to obtain the same level of stakeholder integration as you would expect in a collocated organization [99]. Lack of frequent face-to-face interaction may impair relationship building [22], [87], [91], [99] since relations are build through communication between project stakeholders [87]. The problem also extends to integration of new project participants [6] and other stakeholders in the organization [84]. Closely related to stakeholder relations is the question of trust. Mutual trust is important but hard to obtain in GDSPs [58], [61], [98], [106]. This can be due to lack of face-to-face interaction [20], [74], [109], cultural differences,

and weak social relations [87]. Trust among stakeholders is necessary to achieve innovation, flexibility, cooperation, and efficiency in a distributed environment [2], [13], [20], [30], [42], [44], [59]. Furthermore, since GDSPs often have a short life span, it is important to achieve mutual trust rapidly [41], [91], but if trust is misplaced, the entire organization may suffer [59]. Ultimately, relationship building and mutual trust problems extend to lack of stakeholder commitment [61]. Stakeholders are less likely to commit to the project organization and its task when cultural differences and lack of face-to-face interaction makes it difficult to establish a clear project identity [6], [30], [78]. This weakens group synergy [6], [30], increases the risk of conflicts [78], and may lower efficiency in the initial project phase [105].

H. Communication Infrastructure

Almost every problem arising in GDSPs is related to the fact that communication is no longer a simple task when participants are distributed and appropriate supporting infrastructures are therefore needed. Personal communication is often impeded by absence of informal communication [35], [37] and lack of face-to-face interaction [22], [87]. This can negatively impact trust [47], [100], decision quality [37], [47], creativity [47], [100], and general management [20]. Furthermore it may reduce participants' project overview, which can lead to errors and misunderstandings [37]. Being separated, interaction media becomes the primary communication link between sites, but their properties or use may cause problems such as jumbled sequences of messages; mix-ups between past, present, and future messages [47], [70], [100], [112]; and loss of contextual information sharing [47], [111]. Such problems, arising with either synchronous or asynchronous interaction media, may lead to confusion [100] and misunderstandings [111] among participants and lower the moral [47]. GDSPs are highly dependent on proper teleconference management in order to coordinate efforts between sites. When interaction medium limits verbal and nonverbal cues, it is not possible to apply traditional management of meetings [100], [112]. Additionally, different time zones may make it difficult to organize conferences [5], [12], [88]. These factors make it challenging to benefit from conferences [13], [112].

I. Technology Setup

Networks that connect globally distributed sites are often slow and unstable [22], [37], and even minor delays can ruin the flow of communication [17], [46], [47], [70], [88], [100], [112]. Network capability is therefore an important challenge in GDSPs, and selection of appropriate information and communication technology is crucial for project success [46], [68], [110]. Unreliable networks may lead to frustration and low efficiency [22], limit exchange of sensitive information [10], [88], or even cause production stop [22]. When developers from different parts of the world collaborate, tool compatibility may prove a problem. The reason is that sites are likely to prefer different programming languages, support tools, operating systems, and development tools [22], [46], [100]. Also, the sites may experience

differences in support and tool versions. This can lead to frustrations, conflicts, and delays [100]. Configuration management is specifically a challenging technology in distributed projects due to possible problems concerning tool differences [5], slow and unreliable sites, lacking awareness of product changes, and bug fixes between sites [24], [37], [40].

IV. CONCEPTUALIZING RISK RESOLUTION TECHNIQUES

Thirty-five risk resolution techniques were identified in the reviewed literature. In the following, we present these techniques using the four categories: planning, control, social integration, and technical integration (cf. Table I). The categories were, as mentioned earlier, adapted from McFarlan's [75] generic software risk management framework. We have categorized each resolution technique based on its primary emphasis as each technique very well can apply to more than one domain. Due to the amount of resolution techniques, we opted not to elaborate each in detail; instead, we present one exemplary resolution technique for each category of resolution techniques: a complete list of the identified resolution techniques is presented in Appendix C.

A. Planning

The planning category includes resolution techniques that help plan projects to be effectively executed in distributed contexts. An important planning technique in GDSPs is "create shared collaboration platform," offering a shared vocabulary to describe both everyday activities on each site and central activities in the development process, e.g., by using UML. This promotes unity and sense of belonging and reduces misinterpretations [5], [16], [100]. Also, it is advised to establish a shared project culture without discriminating in favor of any particular national or professional culture. More specific suggestions are the use of a dialogue technique to establish shared mental models of the project and task [105] and the production of concept lists explaining slang across the involved cultures and professions [69].

B. Control

The control category includes resolution techniques that facilitate tracking progress and help manage discrepancies in relation to plans in distributed contexts. An example of a technique that supports control in GDSPs is "establish temporal coordination mechanisms," providing structured approaches to temporal coordination across sites including handling of deadlines, synchronization, and distribution of resources [70], [77]. Shared deadlines or milestones should be introduced when coordinating successive integration of individual software modules as well as handling diversities concerning local festivals and holidays [5], [100]. If reduction of temporal distance is impossible, the project manager should manage time translations and time adjustments, relocate time using asynchronous media, and institute time-based norms for communication and virtual presence [100]. There should also be a focus on synchronization, plans, and procedures in the development process, enabling transferring of tasks from one site to another [99].

C. Social Integration

The social integration category covers resolution techniques that integrate participants and help manage cultural differences across sites in distributed contexts. One of these techniques is “develop liaisons between sites.” This approach advocates using liaisons to facilitate information exchange, identify expertise, mediate cultural conflicts, and settle disputes [5], [12], [24], [35], [36], [56]. If the organization consists of a main site and several subsites, liaisons from the subsites should spend the start-up phase at the main site to gain insight and overview of the project [5]. Furthermore, it is advised to include travel expenses in the overall budget and not perceive them as additional costs.

D. Technical Integration

The technical integration category includes resolution techniques that increase connectivity and technical compatibility across sites in distributed contexts. An example of these resolution techniques is “standardize and train in methods across sites.” This technique suggests standardization of tools, methods, templates, and processes in order to create a harmonic and efficient project organization [24], [25], [56], [99]. Such standardization implies training of participants and lower initial efficiency as experience with the chosen standards varies [5], [25], [46]. In the long run, higher efficiency and fewer misunderstandings are, however, expected [24], [56]. More specific standardization could be introduction of shared guidelines for error handling, accessibility to other sites’ documentation, documentation of tests and testability [40], or the use of a shared tool that allows for tracking of bugs and corrections in all parts of the distributed project [5].

V. AN INTEGRATIVE FRAMEWORK

Based on the insights from the two previous sections, we developed a framework for managing risks inherent in GDSPs. First, we linked resolution techniques to risks based on the literature. Then, we developed a framework for risk assessment, risk control, and risk management planning in GDSPs. Finally, we implemented a Web-based tool called Distributed Project Management System (DPMS) to help refine the framework based on empirical evaluation of its practical usefulness. In the following, we present each of these steps in detail.

A. Linking Resolution Techniques to Risks

Based on the reviewed literature, we linked resolution techniques to risk areas, reflecting which resolution techniques can alleviate which risk areas. To that end, we created a matrix with risk areas on the x -axis and resolution techniques on the y -axis (Table IV). The reviewed articles were then revisited and references were added to the matrix where we identified a link in the literature. This identification process was interpretive rather than literal.

B. Developing Framework

Subsequently, we considered four classical risk management frameworks presented by Lyytinen *et al.* [67]. These were McFarlan’s [75] portfolio framework, Davis’s [18] con-

tingency framework, Boehm’s [7] software risk framework, and Ginzberg’s [32] implementation framework. The design of Ginzberg’s approach [32] did not qualify for our purpose because it does not include risk resolutions. Of the remaining three, we opted for the design of Boehm’s [7] risk-action list framework, as it possesses two important qualities: it is easy to use and modify [39]. We considered ease of use crucial, as the framework should be employed in a distributed and likely cross-cultural context. In such a setting, we made it a priority to enable participants with varying background to use the framework without lengthy preparatory instructions. Regarding easy modification, flexibility is a desirable trait in GDSPs as these organizations have changing needs [22], [37], [108]; also, we considered future development of the framework, taking into account that rapid development of technology and organizational forms plays a major role in GDSPs, making future alterations inevitable. The tradeoff when comparing risk-action list frameworks (e.g., Boehm [7]) with risk-strategy frameworks (e.g., McFarlan [75]) and risk-strategy-analysis frameworks (e.g., Davis [18]) is lack of strategic oversight [39]. However, we did not consider this as important as the other qualities because the proposed risk management framework focuses on risks related to geographical distribution rather than on risks in general. The framework therefore demands complementary management and risk management approaches to provide appropriate strategic oversight.

According to Boehm [7], risk management involves risk identification, risk analysis, risk prioritization, risk management planning, risk resolution, and risk monitoring. Our risk management framework consists of three elements, formalizing these steps in GDSPs (Fig. 2). In terms of content, the framework differs from Boehm’s [7] by specifically focusing on risks related to distributed projects; we exclude risks appearing in collocated projects unless the distributed environment significantly exacerbates them. Additionally, during risk assessment, our framework estimates risk exposure on the risk factor level, opposed to Boehm [7], who evaluates risk exposure on the risk area level.

Our framework supports multiple users in order to engage project participants across sites as illustrated in Fig. 2. This is a crucial feature for risk assessment accuracy, as no single project manager possesses the necessary overview of GDSPs to accurately perform risk management. Another important structural feature is the support of project hierarchies in GDSPs [26]. This allows for subprojects within distributed projects to contribute to an overall risk assessment.

When applying our framework to a GDSP, the first step is risk assessment. This process evolves around a model with the eight identified risk areas and 24 risk factors that constitute the results from the literature review (Fig. 3). For each risk factor, the user selects a risk probability $P(\text{UO})$ (defined as the probability of unsatisfactory outcome [7]) and the loss to the parties affected if the outcome is unsatisfactory $L(\text{UO})$ [7]. These assessments are made on a scale with the numeric values 0–8, categorized into low (0–2), medium (3–5), and high (6–8) (Fig. 3). During probability assessments, users are supported by not only the numeric scale but also by a qualitative interpretation of each measure based on the literature review; see example in Fig. 3 or Table III for the full list. After users have assessed both

TABLE IV
LINKING RESOLUTION TECHNIQUES TO RISK AREAS

Planning	Task Distribution	Knowledge Management	Geographical Distribution	Collaboration Structure	Cultural Distribution	Stakeholder Relations	Communication Infrastructure	Technology Setup
Acquire complementary skills	[10, 103]		[10, 20, 103, 108]	[20, 103, 108]	[69]	[78, 103]	[112]	[10, 103]
Adjust meetings to distributed context	[88]	[13, 22, 56, 112]	[13, 88, 100, 112]				[13, 22, 100, 112]	[13]
Divide tasks systematically between sites	[5, 24, 35, 36]	[5]		[35, 36]				
Reduce coupling between sites	[91, 94]		[12, 91, 94]	[12, 91, 94]				
Create shared collaboration platform		[5, 16, 100, 105]	[5, 16, 77, 100]	[5, 100, 105]	[16, 24]	[68]		[5]
Establish shared goals	[10, 52, 108]	[46]	[6, 10, 30, 46, 52, 104, 108]	[108]		[6, 46, 58, 98, 104]		
Establish communication norms		[47, 88, 100, 111, 112]	[13, 88, 100, 117]		[24]	[69, 111]	[13, 47, 88, 100, 108, 112, 117]	[47, 88, 100, 111, 112]
Define roles and responsibilities			[59, 100]	[117]	[24, 41, 59, 100]	[59]		
Reduce time-zone differences			[12, 99]					
Control	Task Distribution	Knowledge Management	Geographical Distribution	Collaboration Structure	Cultural Distribution	Stakeholder Relations	Communication Infrastructure	Technology Setup
Focus on deliverables		[37]	[77]					[37, 46]
Establish task coordination between sites	[5, 24, 37]			[24]				
Maintain site autonomy	[5]		[5, 6, 25, 52, 89]	[25]		[89]	[5, 52]	
Establish shared control mechanisms	[6]	[25]	[6, 20, 25, 44, 104, 110]	[25]		[20, 44]		
Establish temporal coordination mechanisms	[5]	[99]	[5, 70, 77, 99, 100]	[99]				[100]
Maintain project organization overview	[28]	[28, 35, 36, 100]	[36, 100]	[35]			[74]	[28, 36, 100]
Maintain task overview within and across sites	[5, 6, 28]	[28, 68]	[68]				[68, 105]	[28, 68]
Monitor and improve communication		[88]	[110]			[44]		[88]
Maintain a supportive environment	[82, 97, 110]		[59, 85, 100]		[59]	[58, 59, 85]		[97]
Analyze and manage errors	[40]	[40]						
Social Integration	Task Distribution	Knowledge Management	Geographical Distribution	Collaboration Structure	Cultural Distribution	Stakeholder Relations	Communication Infrastructure	Technology Setup
Improve capability to manage cultural differences		[22]	[22, 104]		[22, 56, 100, 104]			

TABLE IV
CONTINUED

Improve distributed collaboration skills			[13, 30, 85, 91, 100, 104, 108, 111, 117]	[13, 91, 104]		[30, 85]	[13, 108, 112]	
Improve language skills					[12, 22, 24, 88]			[22]
Emphasize early teambuilding activities			[24, 46, 77, 97, 110]			[24, 46, 58, 97, 110]	[35]	[97, 110]
Promote humor and openness			[47, 91]		[91, 104]	[47]		
Use mentors to integrate new members	[6, 30, 105]	[6, 30, 105]				[6, 30, 105]	[105]	
Use face-to-face meetings appropriately	[73, 99]	[10, 97, 110]	[30, 35, 64, 73, 87, 91, 97, 99, 110, 112, 117]	[10]		[30, 35, 64, 87, 91, 97, 99, 110]	[52, 73, 112, 117]	
Develop liaisons between sites	[5, 12, 24, 35, 36, 56]	[5, 12, 24, 35, 36, 56]	[5, 12, 24, 35, 36, 56]		[5, 12, 34, 56]	[35]	[5, 35, 36]	
Adopt shared reward systems				[10]	[108]	[30, 64]		
Technical Integration	Task Distribution	Knowledge Management	Geographical Distribution	Collaboration Structure	Cultural Distribution	Stakeholder Relations	Communication Infrastructure	Technology Setup
Increase technical compatibility between sites		[10]	[10, 22, 46]				[10]	[5]
Standardize and train in methods across sites	[40]	[5, 40]		[5, 25, 99]	[24]			[40, 46]
Adopt appropriate communication technologies	[19]	[1, 10, 17, 101]	[20, 30, 44, 47, 64, 85, 97, 100, 110, 111]		[56, 88]	[30, 44, 47, 64, 90, 111]	[10, 35, 36, 90, 110]	[10, 22, 68-70]
Improve collaboration and communication technology skills		[5, 10, 30, 46, 68, 91, 108]	[68]	[68, 91]		[111]	[5, 10]	[22, 30]
Improve development technology skills		[22, 46, 91, 100]						[91]
Handle differences in methods between sites		[100]		[5, 25, 100]				
Combine waterfall model and prototyping	[99]			[99]				

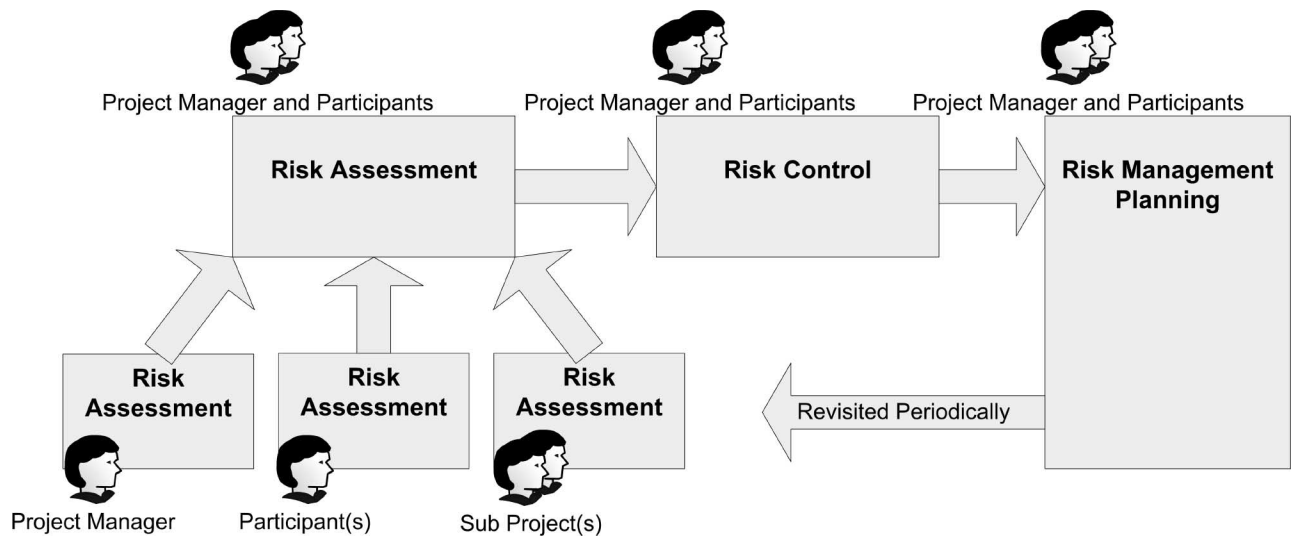


Fig. 2. Framework elements.

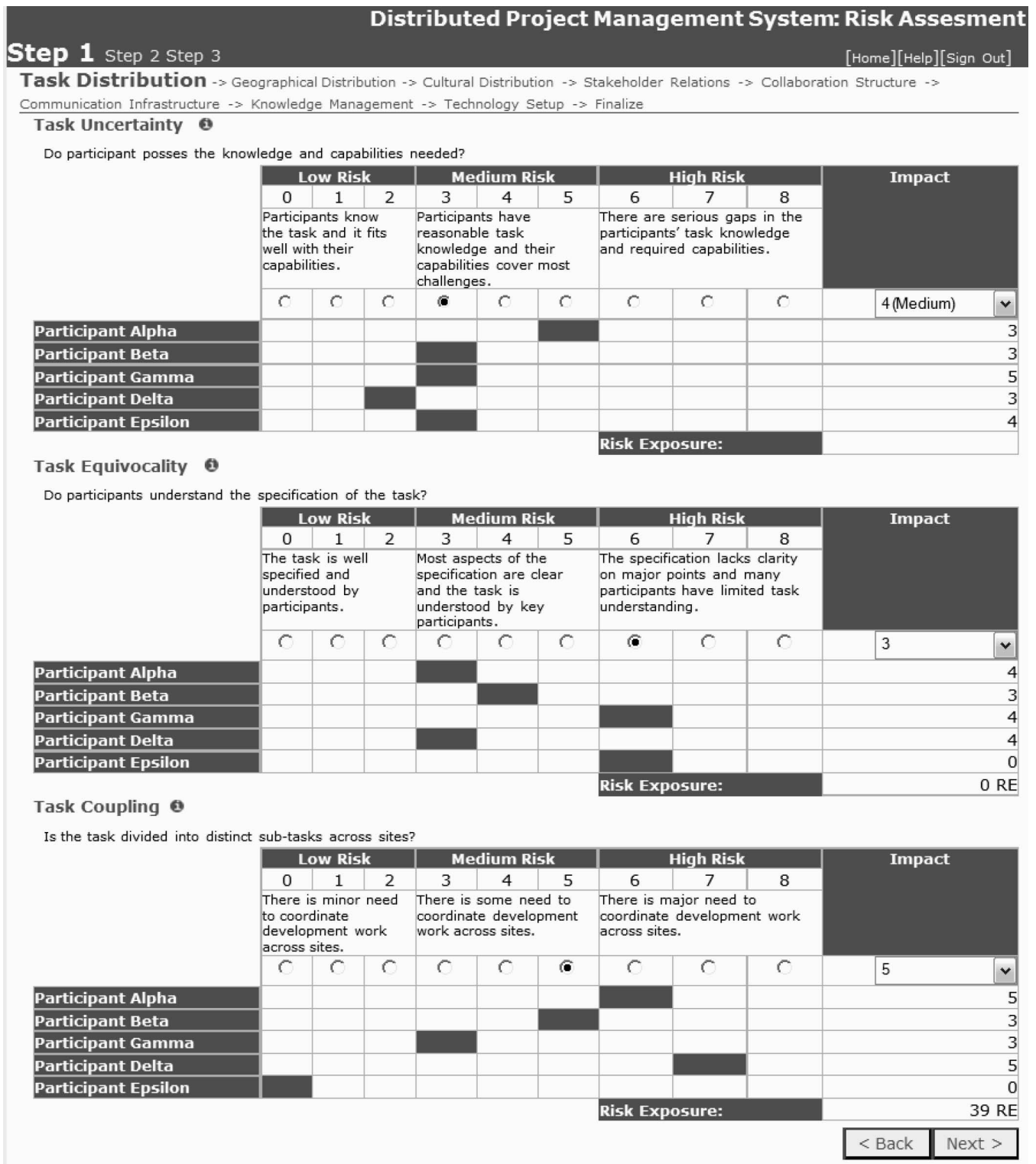


Fig. 3. Risk assessment in DPMS.

the risk probability and impact for a given risk factor, the risk exposure (RE) is calculated based on the equation $RE = P(UO) \times L(UO)$ proposed by Boehm [7]. The average RE for the three risk factors subsequently constitutes the risk area's RE value. Based on these values, a prioritized list of the eight risk areas is derived, representing the significant risk areas in the GDSP.

A number of GDSP participants independently perform a risk assessment. The combined set of assessments subsequently forms the basis for a risk discussion among the participants where the participants share the submitted assessments, as shown in Fig. 3, to allow for direct comparisons. The participants, either collocated or mediated via conference, can then

negotiate a shared risk assessment for the GDSP. In this process, the project manager and participants can obtain valuable insights into and overview over the GDSP [39], [67]. It is the responsibility of the project manager to keep the discussion structured and update the risk assessment according to findings. The discussion may be lengthy or short depending on factors such as differences in opinions and discussion management. The ideal result of the discussion is a risk area prioritization that all participants agree upon.

The risk control step following the assessment also relies upon discussion and knowledge sharing among project participants. The first task is to prioritize which risk areas to address using the risk areas' RE values as support. Next, a set of appropriate resolution techniques is presented for each prioritized risk area based on the heuristics matrix (cf. Table IV), represented by checkmarks linking risk areas to resolution techniques in Fig. 4. The project participants then discuss and choose the resolution techniques considered appropriate for each risk area.

The assessments and selected actions are summarized in risk management plans for each of the prioritized risk areas. These plans lay out the activities necessary to bring the related risk area under control. Each plan contains answers to five basic questions, as proposed by Boehm [7]. The objectives (why) are identified through the risk assessment. The deliverables and milestones (what and when) suggest when the selected actions are to be taken. The project manager is free to structure this as best fits the project. The third area, responsibilities (who and where), describes which individuals are responsible for a given task, and where within the distributed organization, it is to be carried out. The approach (how) consists of the previously identified resolution techniques. The fifth and final area is resources (how much), where the participants estimate the costs associated with addressing the risk area under consideration.

The final step in risk management is to integrate the resulting risk management plans with the overall project plan. This process is not directly supported by the framework due to the diversity of project management methods available. In conclusion, a date should be set for revisiting risk management in order to keep risk management plans up to date with the evolving GDSP.

C. Implementing Web-Based Tool

To allow us to refine the framework based on empirical evaluation of its practical usefulness, the framework was subsequently implemented as a Web-based tool. This DPMS tool implements and elaborates the proposed risk management framework to support practical management of GDSPs. The tool is available at <http://www.distributedprojects.net>. While the framework can also be adopted without this tool or with alternative tools, the presented Web-based tool follows the structure depicted in Fig. 2. As an initial step, the project manager is responsible for registering a project and assigning participants and subprojects. When performing risk assessments, users have the opportunity to draw upon supportive information via hyperlinks. Upon completion, the individual risk assessments are submitted and aggregated to support risk discussion. This is done by arranging the individual risk assessments next to each other on the screen, allowing for direct comparison (Fig. 3). When the shared risk

assessment is completed, a prioritized list of risk areas is presented. To visually aid the users in selecting the proper risk areas to proceed with, risk areas are color coded: $RE > 47 = \text{red}$, $9 < RE < 48 = \text{yellow}$, and $RE < 10 = \text{green}$. In the following step, risk control, users are presented with a schema based on Table IV that illustrates how resolution techniques apply to risk areas. The prioritized risk areas are highlighted. Users then, for each of the chosen risk areas, select a number of resolution techniques. In this process, users can access elaborate information about each resolution technique via hyperlinks (Fig. 4). The final step is risk management planning. The system automatically fills in information regarding "why" and "how" based on results from previous steps. As this information is generic, it can be edited to fit the specific context. The risk management plan is stored and can later be retrieved when revisiting the DPMS.

VI. EVALUATION OF FRAMEWORK

We developed the risk management framework iteratively. The practical usefulness of each version was evaluated, and the findings were fed into the next iteration. In total, four evaluations were conducted with increasing focus on practical usage: Evaluation I focused on the initial conceptualization of risks and risk resolutions through a focus group; Evaluation II focused on paper-based risk assessment and risk management through a focus group and a workshop; Evaluation III focused on tool-based risk management through a workshop; and, Evaluation IV focused on full-scale application of the DPMS tool with multiple participants in a real-world setting. All four evaluations were documented through field notes, audio recordings, and work documents. Table V summarizes the evaluations. The iterative development–evaluation process was terminated at this point as Evaluation IV only led to minor changes and all participants found the risk management framework useful and easy to use. While the practical usefulness of the framework in this way was evaluated with experienced GDSP practitioners, its effect in complex GDSP contexts was not thoroughly evaluated. Additional evaluations that include effects over longer periods of time are, therefore, an important direction for future research, as discussed later.

A. Evaluation I: Focus Group

Evaluation I was carried out as a focus group interview attended by six practitioners representing four different companies: Alpha (2), Beta (1), Gamma (2), and Delta (1). These were mid-sized to large companies within the information technology (IT) industry with software development activities in multiple countries. The companies were chosen due to their usage of both internationally and nationally distributed software projects. The respondents were all project managers with relevant experience in GDSP and risk management. Each project manager had a master's degree equivalent education in computer science or management information systems and minimum five years of industry experience. The evaluation was divided into an inductive and a deductive part. The first part was an explorative, semistructured focus group interview that had as objective to obtain data about the practitioners' own experiences in GDSPs.

Distributed Project Management System: Resolution Techniques

Step 1 **Step 2** Step 3 [Home][Help][Sign Out]

Cultural Distribution -> Knowledge Management -> Communication Infrastructure -> Geographical Distribution -> Stakeholder Relations -> Collaboration Structure -> Task Distribution -> Technology Setup -> Finalize

Language Barriers (7*7)*(100/64) Risk Exposure: 77							
Work Culture (8*6)*(100/64) Risk Exposure: 75							
Cultural Bias (6*7)*(100/64) Risk Exposure: 66							

	Cultural Distribution	Knowledge Management	Communication Infrastructure	Geographical Distribution	Stakeholder Relations	Collaboration Structure	Task Distribution	Technology Setup
<input type="checkbox"/> Acquire complementary skills ⓘ	✓		✓	✓	✓	✓	✓	✓
<input type="checkbox"/> Create shared collaboration platform ⓘ	✓	✓		✓	✓	✓		✓
<input type="checkbox"/> Establish communication norms ⓘ	✓	✓		✓	✓			✓
<input type="checkbox"/> Define roles and responsibilities ⓘ	✓			✓	✓	✓		
<input type="checkbox"/> Adopt appropriate communication technologies ⓘ	✓	✓	✓	✓	✓		✓	✓
<input type="checkbox"/> Maintain a supportive environment ⓘ	✓			✓	✓		✓	✓
<input type="checkbox"/> Improve capability to manage cultural differences ⓘ	✓	✓		✓			✓	✓
<input checked="" type="checkbox"/> Improve language skills ⓘ	✓							✓
<ul style="list-style-type: none"> • Introduce language training. • Establish English as the official language of the organization and introduce language training (if collaboration is intra-organizational). • Use supporting technologies, such as spell checkers and translators. 								
<input type="checkbox"/> Promote humor and openness ⓘ	✓			✓	✓			
<input checked="" type="checkbox"/> Develop liaisons between sites ⓘ	✓	✓	✓	✓	✓		✓	
<ul style="list-style-type: none"> • Use liaisons to facilitate information exchange, identify expertise, mediate cultural conflicts, and settle disputes. 								
<input type="checkbox"/> Adopt shared reward systems ⓘ	✓				✓	✓		

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Fig. 4. Resolution technique selection in DPMS.

The second part was a structured focus group interview that evaluated the proposed conceptualization of risks and resolution techniques. During the first step, the practitioners produced two lists: one containing their view of the ten most significant challenges of GDSPs and the other containing the ten best-suited resolution techniques to address the challenges of GDSPs. For both challenges and resolutions, the participants then had to merge the lists into one through discussion and exchange of experiences. In step two, the participants were presented with the result from the first development cycle: a list of risks and a list of resolution techniques. Each entry in the lists was presented in turn, and the participants were asked to rate the im-

portance of the entry according to their own experience as well as evaluate the communicative value of the adopted formulations. In addition, the practitioners were asked to relate each resolution technique to any number of risk areas they thought relevant.

The findings of the first part showed few inconsistencies between the GDSP challenges and resolutions reported by the practitioners and the lists we had derived from the literature. As was to be expected due to the relative small sample size and the exploratory nature of the evaluation, not every entry of the lists was touched upon during the first part. However, the challenges and resolutions presented by the participants helped us rethink

TABLE V
EVALUATION OVERVIEW (RA: RISK AREA; RF: RISK FACTOR; RT: RESOLUTION TECHNIQUE)

	Evaluation Approach	Evaluation Focus	Data Collection	Number of Participants	Resulting Changes
Evaluation I	Focus Group I	List of risks and risk resolutions	- Semi structured interview - Structured interview	6	- Restructuring: 2 RF - Rewordings: 6 RA; 15 RT - Deletions: 3 RF; - Additions: 5 RF; 3 RT
Evaluation II	Focus Group II	Risk assessment (Paper version)	- Prototype use - Debate - Semi structured interview	5	- Restructuring: 8 RF - Rewordings: 25 RF; 1 RA; 21 RT - Deletions: 2 RA; 1 RF - Additions: 2 RA; 4 RF
	Workshop I	Risk management (Paper version)	- Prototype use - Think aloud - Semi structured interview	1	
Evaluation III	Workshop II	Risk management (Electronic version)	- Framework use - Semi structured interview	2	- 8 major usability improvements and 24 RF support text rewordings
Evaluation IV	Workshop III	Risk management (Electronic version and collocated discussion)	- Framework use - Participant observation - Debate	14	- Rewording of 5 RF and 24 RF support texts

the overall risk categorization and the individual risk factors. The comments to and structured evaluations of the framework during the second part also provided valuable input regarding the communicative qualities of both the adopted conceptions and explanatory texts of risk factors and resolution techniques. A number of formulations were therefore improved. The changes in conceptualizations and approach resulting from Evaluation I are summarized in Table V.

B. Evaluation II: Focus Group

The focus of the first part of Evaluation II was to evaluate the practical usefulness of the framework through discussion and use of individual framework elements. To do this, we organized a focus group consisting of five practitioners from Beta: two project managers, a tester, a system architect, and a developer. This sampling represented two nationalities, Danes and Spaniards, as well as five different projects within Beta. The group was initially introduced to the framework, after which each participant performed a risk assessment and risk area prioritization of their respective projects. Following this, the framework and its usability were discussed and its content and structure evaluated. The second major part of the framework, the selection of suitable resolution techniques and elaboration of a risk management plan, was evaluated based on an exemplary walk-through followed by a semistructured interview of the focus group.

The collected data pointed at a number of areas where the framework needed improvement. One of the most significant areas was that all practitioners, to some extent, had difficulties distinguishing between risk areas and risk factors. This led to confusion and, in some cases, to faulty risk analyses. Additionally, some risk areas were seen as being too interdependent. These findings led to major revision of the framework, rephrasing and restructuring both risk areas and risk factors. Suggestions regarding implementation of the framework as a Web solution gave inspiration for the continued development of the framework. Further remarks emphasized using risk assessment as a collective discipline involving a broad selection of project participants as well as considering how the design impacted the general flexibility of the risk management process, e.g., adding the option to alter the calculated RE before

proceeding to create a risk management plan. Finally, the evaluation pointed out that the framework did not sufficiently include configuration management, which was seen as a major risk factor in GDSPs. These remarks were carefully considered and subsequently implemented into the framework. The changes in the framework resulting from the focus group part of Evaluation II are summarized in Table V.

C. Evaluation II: Workshop

The second part of Evaluation II was carried out in a workshop setting. The evaluated version of the framework corresponded to the one evaluated in the second focus group interview. There were two objectives: to evaluate the individual parts of the framework (risk assessment, risk control, and risk management planning), the information transfer between them, and the users' understanding of them and to evaluate the overall usability of the framework and its contribution to management of GDSPs. The workshop had only one participant, a project manager at Gamma with extensive experience in both GDSPs and risk management. The participant was introduced to the framework and then proceeded to apply it to his current project. While using the framework, he was asked to think aloud and account for his choices. This approach was inspired by the think aloud test, frequently used in software usability testing [96]. Upon completion of the risk management plan, the participant was debriefed using a semistructured interview.

The overall assessment was that the framework was practically useful; especially, the coupling between risk areas and resolution techniques gave rise to positive feedback. The project manager found that texts in the framework had an appropriate level of abstraction and generally were easy to read. Some risk factors caused confusion, which further contributed to revising risk areas and risk factors (see section VI-B). In general, the participant was reluctant to read the explanatory texts associated with each risk factor. This was taken into account as it further emphasized demands for short, precise formulations. Additionally, comments were given that correspond well to the findings of the focus group part of Evaluation II—configuration management should be emphasized in the model—and it was considered important that project participants participate in the risk assessment as no project manager has sufficient overview to

perform it alone. The changes in the framework resulting from the workshop part of Evaluation II are summarized in Table V.

D. Evaluation III: Workshop

The third evaluation took place during the third iteration of developing the framework. At this stage, the risk management framework was implemented as the DPMS tool. The evaluation focus was fourfold: usability, presentation of content, distributed usage, and workflow. To that end, we arranged a workshop with a project group at Alpha that was collaborating with an Indian business partner. Two members of the project participated, the project manager and the business developer. The workshop was divided into two parts, held with one-day interval. During the first part, the two participants completed a risk assessment of their project separately and independently. The project manager performed the initial steps of registering a new project and adding participants to the system before proceeding to make the risk assessment, whereas the business developer performed the risk assessment. Similar to the second part of Evaluation II, both were asked to think aloud, allowing us to follow their train of thought [96]. In the second part, the two participants were brought together and used the tool to perform a shared risk assessment, select appropriate resolution techniques, and create a risk management plan for the project. Upon completion, we debriefed the participants using a semistructured interview.

The participants found the risk assessment part of the framework useful and easy to use, both during the individual assessment and the combined assessment. However, the initial registration process needed improvement as the project manager found it somewhat confusing. The coupling between risk areas and resolution techniques also caused initial problems as the tool did not clearly indicate the process status. Presentation-wise, the risk management plan proved problematic as the elaborating text provided by the tool was perceived as inhibitory rather than helpful. The participants requested greater flexibility to customize the content to their particular project. Concerning distributed usage, the shared risk assessment and the related discussions were considered beneficiary and well supported by the tool. These findings led to revision of the visual presentation of the framework taking the identified usability problems into consideration. Additionally, the risk management plan was altered as the elaborate texts were made accessible to the user during each step rather than presented upfront. Finally, indicators of progress were added to each step of the framework to visualize the user's status in the process. The changes in the framework resulting from Evaluation III are summarized in Table V.

E. Evaluation IV: Workshop

Evaluation IV was carried out in a project at a large fifth company, Epsilon, not involved in the previous evaluations. The evaluation focus was on full-scale framework application, with multiple participants in a GDSP. The project had 18 participants, 4 placed in Finland and 14 in Denmark. The workshop included all the Finnish participants and ten of the Danish participants and took place by the end of the requirements specification phase. The workshop was divided into three activities over a

two-day period. The first activity, individual risk assessments, was conducted the first day with the DPMS tool and facilitated by one of the authors through individual 15-min sessions with each participant. The second activity consisted of following the remaining steps in the risk management framework. First, each risk area was discussed and reassessed based on the presentation of the individual assessments. Second, the risk area with the highest risk exposure was chosen, and appropriate resolution techniques for that specific risk area were selected and planned. The third and final activity was a group debate of how the participants experienced the framework.

The overall assessment was that the framework was useful in facilitating awareness among project participants of important challenges related to geographical distribution. The four hours each participant used on the framework was considered well spent. During the discussions, the participants spent a significant amount of time on making sense of and applying the concepts to their specific project context. This was necessary in order to clarify project roles across participants and sites and to exchange the different frames of reference caused by geographical distribution of the project. These discussions were considered at least as valuable as the resulting planning documents. The individual assessments were pointed out as an important prerequisite for a valuable discussion. The 15 min allocated for individual assessment was, however, deemed to be too little time; it was estimated that 45 min on average was required for individual assessments. The participants pointed out, that the Web-based tool used risk aversive language in describing overall levels of risk factors. Instead of indicating an "unsatisfactory" risk level we relabeled it to "high." The changes in the framework resulting from Evaluation IV led to the current version of the framework.

VII. DISCUSSION AND IMPLICATIONS

GDSPs are becoming increasingly common. This trend is driven by global competition, increased need for flexibility, access to global resources, and substantial financial gains [37], [91]; moreover, available electronic communication infrastructures make GDSPs increasingly feasible to organize and manage [97], [101]. Although GDSPs have developed into a fertile area of research, there are no comprehensive management frameworks available for this type of organization [25], [91]. Our study took steps toward filling this void by applying risk management [4], [7], [39], [67], [75] to review and synthesize the state-of-the-art knowledge on GDSPs (e.g., [6], [37], [91], [99], [108]). As a result, we developed new risk concepts and a risk management framework, as summarized in Fig. 5.

Specifically, we carried out the research objective to "integrate the existing knowledge into a practically useful framework for managing risks inherent in GDSPs" through two activities. First, we synthesized current knowledge into conceptualizations of risks and resolution techniques and integrated these into a risk-action list framework [7], [39] for GDSPs. The framework consists of three primary elements: risk assessment, risk resolution, and risk management planning, and it

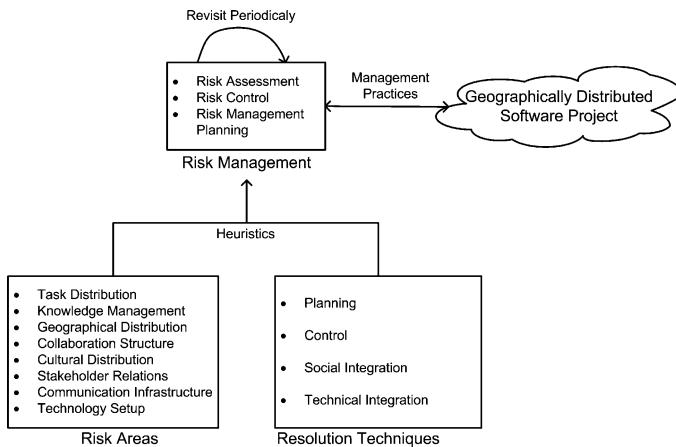


Fig. 5. Summary of research.

provides heuristics for applying four types of resolution techniques to eight risk areas (Table IV). The synthesizing activity drew on the existing literature to help develop clear and distinct conceptions of both risks and resolution techniques. We used available surveys of challenges in GDSPs to identify relevant risk areas consistent with the state-of-the-art knowledge (Table II); used Leavitt's systems model [60], as proposed by Lyytinen *et al.* [67], to clarify the primary focus of the identified risk areas (Table II); aggregated a complete list of risk factors identified in the literature and categorized them according to the proposed risk areas; and finally, further characterized each risk area through detailed definitions of the involved risk factors (Table III). Concerning risk resolution techniques, we adapted McFarlan's [75] well-established categories of project management techniques to distributed contexts (Table I). Finally, concerning heuristics for applying resolution techniques to risk areas, we based our framework on systematically applying the state-of-the-art research on GDSPs (Table IV).

Second, we revised the framework iteratively based on evaluations of its practical usefulness [81]. To that end, we drew on a variety of empirical evaluation methods. Initially, we had experienced how software practitioners assess the relevance and understandability of both risk and risk resolution concepts through two focus groups (Table V). Three subsequent evaluations aimed at assessing the practical use of the framework through workshops with experienced practitioners (Table V); to support the last two workshops, we implemented a Web-based tool, DPMS, thereby making the framework readily available for practical use. In conclusion, the framework was found to be easy to use and to provide relevant support for managing the projects under consideration. Section VI describes the evaluation activities and the iterative changes to the framework (Table V). Throughout the paper, we have consistently presented the final version of the framework.

The framework is, in this way, based on systematic synthesis of the literature and systematic evaluation of practical usefulness. Still, the presented research has notable limitations. First, we have provided only preliminary evaluations of the practical usefulness of the proposed framework. There is a need for more

research into the utility of the framework across different types of contexts. Second, the set of 72 articles from which the synthesis of risks, resolution techniques, and heuristics are derived is limited due to the adopted criteria for selecting literature; we acknowledge the existence of additional articles, books, and other sources, which could potentially contribute to risk management for GDSPs. Third, the participants in our evaluations were of Danish, Spanish, and Finnish origin; this means that cultural challenges of framework usage, e.g., potential differences in interpretation of explanatory texts, rigor of framework application, or different perceptions of project management, need further investigation.

The integrative framework makes a contribution to the literature on GDSPs. It is, to our knowledge, the first comprehensive framework for managing risks in this increasingly important type of software project. The framework provides an overview and synthesis of the state-of-the-art knowledge, provides conceptualizations of risks and resolution techniques related to GDSPs, and opens for a number of interesting research opportunities. A combination of action research and case studies could investigate practical, long-term effects on GDSPs and interactions with the organizational and cultural context and with other managerial control mechanisms [53], [54]; address the recent call for research on control in distributed environments [54], [91]; and investigate the effects on knowledge sharing and cohesion in GDSPs. Future experiments could compare and contrast differences in management behavior between subjects with and without risk management support and test for differences across contexts supported by the overall project risk measures published by Barki *et al.* [4] or Keil [49]. Finally, our research calls for further investigations into available resolution techniques. Such studies could help us learn more about resolution techniques by investigating how effectively they support risk management decisions and managerial strategies in different contexts. Such studies could also draw on the schema of heuristics between risk areas and resolution techniques (Table IV) and adopt design science research to develop and combine techniques to address more risk areas.

The framework also has important implications for management practices within the software industry. The framework demonstrates the complex nature of risks in GDSPs, and it offers concepts and heuristics that practitioners can use to assess and control the risks they face in specific projects. The framework can be used by project managers and participants at any stage of a GDSP, but it is recommended to revisit risk management regularly during a project's lifetime, as illustrated in Fig. 5. On one level, the framework provides participants in GDSPs with a vocabulary they can use to identify, reflect on, and share management problems and solutions [8], [102]. This vocabulary is summarized in Fig. 5. On another level, the framework provides support for assessing risks (Table III) and identifying appropriate resolution techniques (Table IV). Practitioners are generally advised to go through the steps of risk assessment, risk control, and risk management planning, as summarized in Fig. 2 and described in detail in Section V; one possible implementation of the framework as a Web-based tool is made available at <http://www.distributedprojects.net>.

APPENDIX A: JOURNAL LIST

Academy of Management Journal
 Academy of Management Review
 ACM Computing Surveys
 ACM Special Interest Group Publications
 ACM Transactions (various)
 Administration and Society
 Administrative Science Quarterly
 AI Magazine
 American Journal of Sociology
 American Psychologist
 American Sociological Review
 Arbitration Journal
 Artificial Intelligence
 Australian Journal of Information Systems
 California Management Review
 Communications of the ACM
 Communications of the AIS
 Computer Journal
 Computer Supported Cooperative Work
 Computers and Operations Research
 Database
 Database Programming and Design
 Decision Sciences
 Decision Support Systems
 European Journal of Information Systems
 Expert Systems with Applications
 Harvard Business Review
 Human Relations
 Human Resource Management
 Human-Computer Interaction
 IBM Systems Journal
 IEEE Computer
 IEEE Software
 IEEE Transactions (various)
 Industrial and Labor Relations Review
 Industrial Relations
 Information & Management
 Information and Organization (formerly Accounting, Management, and IT)
 Information and Software Technology
 Information Resources Management Journal
 Information Science
 Information Systems
 Information Systems Journal
 Information Systems Management
 Information Systems Research
 Interfaces (INFORMS)
 International Journal of Human-Computer Studies
 International Journal of Information Management
 International Journal of Man-Machine Studies
 International Journal of Technology Management
 Journal of Applied Behavioral Science
 Journal of Applied Psychology
 Journal of Business Research
 Journal of Business Strategy
 Journal of Collective Negotiations in the Public Sector
 Journal of Computer and System Sciences
 Journal of Computer Information Systems
 Journal of Conflict Resolution
 Journal of Database Administration
 Journal of Education for Management Information Systems
 Journal of Engineering and Technology Management
 Journal of General Management
 Journal of Global Information Management
 Journal of Global Information Technology Management
 Journal of Human Resources
 Journal of Information Management
 Journal of Information Science
 Journal of Information Systems (accounting)
 Journal of Information Systems (education)
 Journal of Information Systems Management
 Journal of Information Technology
 Journal of Information Technology Management
 Journal of International Business Studies
 Journal of International Information Management
 Journal of Management
 Journal of Management Information Systems
 Journal of Management Studies
 Journal of Management Systems
 Journal of Occupational Psychology
 Journal of Organizational Behavior
 Journal of Personality and Social Psychology
 Journal of Strategic Information Systems
 Journal of Systems and Software
 Journal of Systems Management
 Journal of the ACM
 Journal of the AIS
 Journal of the American Society for Information Science
 Journal of Vocational Behavior
 Journal on Computing
 Knowledge Based Systems
 Labor Law Journal
 Long Range Planning
 Management Science
 MIS Quarterly
 MISQ Discovery
 Monthly Labor Review
 Omega
 Operations Research
 Organization Science
 Organizational Behavior and Human Decision Processes
 Organizational Dynamics
 Organizational Studies
 Personnel Psychology
 Psychological Bulletin
 Psychological Review
 Research in Organizational Behavior
 Scandinavian Journal of Information Systems
 Sloan Management Review
 Social Forces
 Strategic Management Journal
 WIRT (Wirtschaftsinformatik)

APPENDIX B:
REVIEWED ARTICLES

Journal	Article	Ref.
IEEE TRANSACTIONS ON PROFESSIONAL COMMUNICATION (7)	Panteli, N; Davison, RM (2005)	[84]
	Sarker, S; Sarker, S; Nicholson, DB; Joshi, KD (2005)	[101]
	Ocker, RJ (2005)	[82]
	Bradner, E; Mark, G; Hertel, TD (2005)	[9]
	Rutkowski, AF; Vogel, DR; Van Genuchten, M; Bemelmans, TMA; Favier, M (2002)	[97]
	Vogel, DR; van Genuchten, M; Lou, D; Verveen, S; van Eekout, M; Adams, A (2001)	[110]
	Tan, BCY; Wei, KK; Huang, WW; Ng, GN (2000)	[105]
IEEE SOFTWARE (6)	Carmel, E; Agarwal, R (2001)	[12]
	Herbsleb, JD; Moitra, D (2001)	[37]
	Ebert, C; De Neve, P (2001)	[24]
	Heeks, R; Krishna, S; Nicholson, B; Sahay, S (2001)	[34]
	Battin, RD; Crocker, R; Kreidler, J; Subramanian, K (2001)	[5]
	Herbsleb, JD; Grinter, RE (1999)	[35]
	Paul, S; Samarah, IM; Seetharaman, P; Mykytyn, PP (2004)	[85]
JOURNAL OF MANAGEMENT INFORMATION SYSTEMS (5)	Pauleen, DJ (2003)	[87]
	Massey, AP; Montoya-Weiss, MM; Hung, YT (2003)	[70]
	Kayworth, TR; Leidner, DE (2001)	[47]
	Dennis, AR; Wixom, BH (2001)	[19]
	Dubé, L; Paré, G (2001)	[22]
COMMUNICATIONS OF THE ACM (4)	Sabherwal, R (1999)	[98]
	Taylor, H (2006)	[106]
	Krishna, S; Sahay, S; Walsham, G (2004)	[56]
INFORMATION & MANAGEMENT (4)	Paul, S; Seetharaman, P; Samarah, I; Mykytyn, PP (2004)	[86]
	Lander, MC; Purvis, RL; McCray, GE; Leigh, W (2004)	[58]
	Larsen, KRT; McInerney, CR (2002)	[59]
	Lurey, JS; Raisinghani, MS (2001)	[64]
ORGANIZATION SCIENCE (4)	Hinds, PJ; Bailey, DE (2003)	[38]
	Cramton, CD (2001)	[17]
	Maznevski, ML; Chudoba, KM (2000)	[73]
	Jarvenpaa, SL; Leidner, DE (1999)	[41]
INFORMATION SYSTEMS JOURNAL (3)	Chudoba, KM; Wynn, E; Lu, M; Watson-Manheim, MB (2005)	[16]
	Furst, S; Blackburn, R; Rosen, B (1999)	[30]
	Warkentin, M; Beranek, PM (1999)	[111]
ACADEMY OF MANAGEMENT JOURNAL (2)	Montoya-Weiss, MM; Massey, AP; Song, M (2001)	[77]
IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT (2)	Kirkman, BL; Rosen, B; Tesluk, PE; Gibson, CB (2004)	[52]
	Lee, JN; Kim, YG (2005)	[61]
INFORMATION AND SOFTWARE TECHNOLOGY (2)	McDonough, EF; Kahn, KB; Griffin, A (1999)	[74]
	Jacobs, J; van Moll, J; Krause, P; Kusters, R; Trienekens, J; Brombacher, A (2005)	[40]
INFORMATION SYSTEMS RESEARCH (3)	Sakthivel, S (2005)	[99]
	Majchrzak, A; Malhotra, A; John, R (2005)	[68]
	Jarvenpaa, SL; Shaw, TR; Staples, DS (2004)	[42]
JOURNAL OF INFORMATION TECHNOLOGY (2)	Choudhury, V; Sabherwal, R. (2003)	[15]
	Breu, K; Hemingway, CJ (2004)	[10]
	Klepper, R (1995)	[55]
ORGANIZATIONAL DYNAMICS (2)	Pauleen, DJ; Yoong, P (2001)	[88]
	Zigurs, I (2003)	[117]
ACADEMY OF MANAGEMENT EXECUTIVE (1)	Cascio, WF; Shurygailo, S (2003)	[13]
DATABASE FOR ADVANCES IN INFORMATION SYSTEMS (1)	Townsend, AM; DeMarie, SM; Hendrickson, AR (1998)	[108]
DECISION SCIENCES (1)	Powell, A; Piccoli, G; Ives, B (2004)	[91]
EUROPEAN JOURNAL OF INFORMATION SYSTEMS (1)	Warkentin, ME; Sayeed, L; Hightower, R (1997)	[112]
EUROPEAN MANAGEMENT JOURNAL (1)	Sarker, S; Sahay, S (2004)	[100]
GROUP & ORGANIZATION MANAGEMENT (1)	Kayworth, T; Leidner, D (2000)	[46]
HARVARD BUSINESS REVIEW (1)	Bell, BS; Kozlowski, SWJ (2002)	[6]
HUMAN RESOURCE MANAGEMENT (1)	Majchrzak, A; Malhotra, A; Stamps, J; Lipnack, J (2004)	[69]
IEEE TRANSACTIONS ON SOFTWARE ENGINEERING (1)	DeRosa, DM; Hantula, DA; Kock, N; D'Arcy, J (2004)	[20]
INDUSTRIAL MANAGEMENT & DATA SYSTEMS (1)	Herbsleb JD, Mockus A (2003)	[36]
INFORMATION AND ORGANIZATION (1)	van der Smagt, T (2000)	[109]
INFORMATION SYSTEMS (1)	Nicholson, B; Sahay, S (2001)	[80]
INFORMATION SYSTEMS MANAGEMENT (1)	Farshchian, BA (2001)	[28]
INTERNATIONAL JOURNAL OF CONFLICT MANAGEMENT (1)	Ramarapu, N; Parzinger, MJ; Lado, AA (1997)	[93]
INTERNATIONAL JOURNAL OF HUMAN-COMPUTER STUDIES (1)	Mortensen, M; Hinds, PJ (2001)	[78]
INTERNATIONAL JOURNAL OF INFORMATION MANAGEMENT (1)	Potter, RE; Balthazard, PA (2002)	[90]
JOURNAL OF AMERICAN SOCIETY FOR INFORMATION SCIENCE AND TECHNOLOGY (1)	Khalfan, AM (2004)	[51]
JOURNAL OF COMPUTER INFORMATION SYSTEMS (1)	Alavi, M; Tiwana, A (2002)	[1]
JOURNAL OF ENGINEERING AND TECHNOLOGY MANAGEMENT (1)	Xue, YJ; Sankar, CS; Mbarika, VWA (2004)	[116]
JOURNAL OF MANAGEMENT (1)	Evaristo, JR; Scudder, R; Desouza, KC; Sato O (2004)	[25]
JOURNAL OF STRATEGIC INFORMATION SYSTEMS (1)	Shin, Y (2004)	[103]
MIS QUARTERLY (1)	Kanawattanachai, P; Yoo, Y (2002)	[44]
ORGANIZATIONAL BEHAVIOR AND HUMAN DECISION PROCESSES (1)	Piccoli, G; Ives, B (2003)	[89]
PERSONNEL JOURNAL (1)	Alge, BJ; Wiethoff, C; Klein, HJ (2003)	[2]
PROCEEDINGS OF THE 35 TH ANNUAL HAWAII INTERNATIONAL CONFERENCE ON SYSTEM SCIENCES (1)	Solomon, CM (1995)	[104]
	Ramesh, V ; Dennis, AR (2002)	[94]

APPENDIX C: RESOLUTION TECHNIQUES

*Planning***Acquire complementary skills**

- Involve representatives from other sites in recruitment of new project participants [15].

Important qualities and competencies consist of:

- Patience, stamina, and persistence [112].
- Appreciation of autonomy, flexibility, and diversity [103], [112].
- Trustfulness, reliability, lateral abilities, and skills in virtual communication [103], [108].
- Domain knowledge, computer literacy, and skills in time coordination [10], [103].
- Highly developed collaboration skills [108].
- Understanding of different cultures [108].
- Experience in mediated collaboration [20].
- Homogeneity with respect to culture and education [56], [78].

Adjust meetings to distributed context

- Identify subjects of the meeting subsequently to determine the relevant participants [100], [112].
- Determine the requirements of the meeting. If visual aids are necessary, a videoconference may be appropriate [13].
- Ensure well-prepared participants by sending agenda and other important documents prior to the meeting. Participants should additionally be informed if they are expected to have material ready for the meeting [13], [112].
- Elect a presiding officer (PO) of the meeting to ensure appropriate turn taking and compliance of the agenda [112].
- The PO should summarize discussions periodically during meetings [22], [56].
- The PO should keep an attendance register and ask the participants to introduce themselves at the beginning of the meeting as well as upon speaking [13].
- In the case of a telephone conference: The PO should describe activities in the room, people coming and going, and drawn objects [13].
- Alleviate drawbacks, i.e. in terms of odd work hours, of time zone differences by using fixed meeting schedules. Additionally by “sharing the pain”, distributing drawbacks equally among participants [13], [88], [100].

Divide tasks systematically between sites

- Focus on initial analysis of the modular structure to identify dependencies and predict the effects of changes [36].
- Distribute tasks prioritized according to placement of expertise and local advantages, e.g., proximity to customer [5].
- Base the task distribution on a well-devised modular design that takes the project structure into account. Segmented tasks should be thoroughly understood and expectedly stable [35], [36].
- Keep development and maintenance separate [24].
- Segment the task based on different user requirements [24].
- Segment the system horizontally in clusters with end-to-end functionality. Each group has the responsibility for any and all aspects of functions across system layers in the appointed cluster [5].

- Define an architecture “light” with few, but important principles. The architecture should describe the entire system on a high level of abstraction [5].
- Segment the system sequentially, such that each element is parsed on only upon completion, e.g., from development to test [24], [36].

Reduce coupling between sites

- Reducing dependencies between sites can be done in two ways: Provide well-defined work areas and thereby give the participants minimal control, or give extensive responsibility and thereby full participant control [12].
- Use object-oriented groups. As with object-oriented programming, tasks are split with well-defined interfaces allowing for separation of the groups [91], [94].
- Combine with: *Divide tasks systematically between sites* [5].

Create shared collaboration platform

- Introduce a shared vocabulary to describe both everyday activities in the organization and central activities in the development process, thereby promoting unity and sense of belonging and reducing misinterpretations, e.g., using UML [5], [16], [100].
- Use dialogue technique to establish shared mental models of the organization and tasks. The dialogue technique is further elaborated by Tan *et al.* [105].
- Produce lists of concepts, explaining slang expressions of the involved cultures and professions [69].
- Utilize a shared tool to track bugs and corrections in every part of the distributed organization, thereby providing transparency [5].
- Establish shared project culture without discriminating in favor of any particular national or professional culture [WS1].
- Combine with: Establish shared goals [24], [46].

Establish shared goals

- The project manager should explicitly relate the distributed project organization to the overall strategy, mission and vision, and communicate the purpose of the task [10], [15], [52], [58].
- The project manager should establish and obligate the participants to a shared project goal to develop a common identity [6], [24], [30], [46], [98], [104].
- The project manager should act both proactively and creatively by periodically updating participants about progress towards the planned goals [46].
- Institute a program of implementation that puts focus on the project contribution and relates it to the participants’ present qualities and contribution to the company and its products [108].
- Combine with: *Improve Distributed collaboration skills* and *Improve collaboration and communication technology skills* [111].

Establish communication norms

- The project manager should institute time-based norms for communication, virtual presence, and development of solidarity to encourage tolerance of silences and delayed responses [100].

- Create formal guidelines for the use of asynchronous media that include descriptions of what the communication should contain and how it should be performed [88], [111].
- Set up rules for carrying out written communication, e.g., during chat sessions. Rules should include the use of sarcasm, jokes, the use of capital letters. Ensure that language use is not misinterpreted [111], [117].
- Include contextual information in the communications, such as name, title, and position to facilitate the development of social relations [13], [117].
- Establish conventions for answering messages in, e.g., instant messaging or email. This could include using the 'reply' function or explicitly naming receiver [47], [100], [112].
- Create clear policies for personal privacy [108].

Define roles and responsibilities

- At project startup, define undisputed areas of responsibility for all participants as well as the relational roles being instituted [24], [41], [46], [47], [51], [117].
- The project manager should act as role model and demonstrate the efficiency, quality, and skills needed to create mutual respect in the distributed environment [59].
- The project manager should exercise authority to ensure the completion of delegated assignments [46], [47].

Reduce time-zone differences

- Choose remote sites in the same or proximate time zones, thus alleviating time distance [12], [99].

Control

Focus on deliverables

- Plan and control critical deliverables perfectly considering differences in, e.g. tools and data format [22], [37].

Establish task coordination between sites

- Adjust the project structure dynamically to the individual phases of the project to avoid bottlenecks and waste of resources [97].
- Define clear-cut criteria for both beginning and end of the different project phases [37].
- Use incremental integration of task segments, and avoid the 'big bang' at the end of the project [5].

Maintain site autonomy

- Make sites self-managing by establishing a system that allows participants to monitor own processes [6], [25], [55].
- Be careful using traditional mechanisms for behavioral control as well as managerial interventions as focus on deadlines and progress can lead to mistrust [89].
- Introduce team empowerment [5], [52].

Establish shared control mechanisms

- Design a method to monitor and control the information flow concerning project status, providing information to all stakeholders including the individual groups [25], and accept the administrative overhead [WS1].
- Let participants themselves monitor changes in their environment [6].
- The project manager should make sure that periods of inactivity are detected and reported automatically [110].
- Deploy tools to measure trust in the project's early stages [44].

- Emphasize focus on results and performance compared to traditional projects [20], [104].

Establish temporal coordination mechanisms

- Use structured mechanisms for temporal coordination, including handling of deadlines, synchronization, and distribution of resources [70], [77].
- Introduce shared deadlines or milestones when coordinating successive integration of individual software modules as well as handling diversities concerning local festivals and holidays [5], [59], [100].
- If reduction of temporal distance is impossible: The project manager should manage time translations and time adjustments, relocate time using asynchronous media, and institute time-based norms for communication and virtual presence [12], [99].
- Focus on synchronization, plans, and procedures in the development process, enabling transferring of tasks from one site to another [15], [99].

Maintain project organization overview

- Make the lines of communication as short as possible [74].
- Create a clear plan of communication based on individual and group communication needs. The plan should further contain a list of contacts and their professional and decision making competencies [35].
- Create a database that contains the areas of expertise of the individual project participants [28], [36], [100].
- Use IT systems such as instant messaging to determine availability of participants [36].
- Make internal group decision processes transparent by exchanging meeting résumés between sites [100].
- Combine with: *Define roles and responsibilities* [24], and *Adopt appropriate communication technologies* [36].

Maintain task overview within and across sites

- Define an architecture "light" with few, but important principles. The architecture should describe the entire system on a high level of abstraction [5].
- At project startup: Define clearly, which groups are involved in the project, and which tasks they work on [68].
- Create a project website that summarizes project content, progress, planning, and group related information [68].
- Use dialogue technique to establish shared mental models of the organization and tasks. The dialogue technique is further elaborated in Tan *et al.* [105].
- Utilize a model (software system), which supports consciousness about the development at remote sites, focusing on which information should be conveyed to whom [28].
- Use a content management system (CMS) [WS1].
- Evaluate the task complexity considering task structure, task environment, and internal and external coupling [6].

Monitor and improve communication

- Intervene often and rapidly in the communication and provide frequent feedback to the participants [47].
- The project manager should intervene rapidly if there is a minimal risk of a problem not being resolved [110].
- Provide tools and strategies for early conflict management [44].

- The project manager should control the amount and the quality of the mediated communication [88].

Maintain a supportive environment

- Use a supportive non-dictating management style [110].
- Express flexibility and empathy towards the participants [46], [58].
- The project manager should act as role model and demonstrate the efficiency, quality, and skills needed to create mutual respect in the distributed environment [59], [100].
- The management style should not be characterized by surveillance [59].
- Use “Collaborative conflict management style” (high interest in other’s opinion and high interest in own opinion) [85], [86].
- Avoid creativity inhibiting factors, e.g., time pressure and overly firm structure [82].
- Create heterogeneous groups [82].
- The project manager should set a good example, producing creative ideas — especially in the startup phase [82].
- Prioritize iterative processes in both problem specification and design [82].
- Choose ICT that supports a decentralized network between participants, enhancing information flow and generation of new ideas [97].
- Combine with: *Create a shared collaboration platform* [82] and *Increase technical compatibility between sites* [82].

Analyze and manage errors

- Jacobs *et al.* [40] present a long list of potential causes for errors and delays. We find this too extensive to be presented here. No particular resolution technique is presented in the article, but the individual entries in the list are in our opinion sufficiently specific to be converted to such.

Social Integration

Improve capability to manage cultural differences

- Establish courses in cultural diversity during the startup phase of the project. If participants are stationed at remote sites, the cultural training should take place before departure [22], [56].
- Focus on creating understanding and acceptance of differences, e.g., by letting each participant make a presentation on their individual culture, values, and expectations [22], [104].
- Promote understanding and acceptance rather than seek to streamline the project organization [WS1].
- Focus on the strengths that diversity offers rather than the weaknesses [22], [100].
- Acknowledge and discuss cultural differences in a respectful and civilized manner [104], and keep in mind that there are limits to cultural adaptation [56].
- Adjust management style according to culture, e.g., participants’ preferences for well-defined tasks vs. preference for loosely defined task and self-management [WS1].
- Combine with: *Promote humor and openness* [47], [91].

Improve distributed collaboration skills

- Educate and train participants in collaboration skills specific for the distributed environment [13], [22], [30], [85],

[91], [100], [104], [108], [111], [117]. Skills are divided into three main areas: Virtual collaboration skills, virtual communication skills, and virtual socialization skills [13].

- Focus on creating task- and group related processes [30], [108].
- Offer training rather than relying on localized best practices [117].
- Conflict management should be part of the training [85].
- Seek to obtain a dialogue rather than a two-way monologue in the communication [109].
- Combine with: *Improve capability to manage cultural differences* [104].

Improve language skills

- Introduce language training [24], [88].
- Establish English as the official language of the organization and introduce language training (if collaboration is intra-organizational) [24].
- Use supporting technologies, such as spell checkers and translators [22].

Emphasize early teambuilding activities

- Stimulate the interaction between participants already from project startup [46], [58], [98], [110].
- Arrange videoconferences if face-to-face meetings are impossible [97], [110].
- Create cross functional groups in the initial phase of the project to encourage social relations across areas of expertise [24].
- Combine with: *Use mentors to integrate new members* [105].

Promote humor and openness

- Stimulate relationship building by using humor [47], [91].
- Use humor to enhance cultural understanding by making fun of differences instead of ignoring them [104].
- Promote openness to avoid hidden agendas that impede productivity [WS1].

Use mentors to integrate new members

- Use mentors to integrate new participants. The mentor is responsible for social adaptation and communication of the project and group’s history and values [6], [30], [103], [105].

Use face-to-face meetings appropriately

- Prioritize face-to-face meetings to develop trust and shared identity easier and faster [30], [34], [35], [64], [87], [91], [117].
- Use the “Sandwich structure”, i.e., hold face-to-face meetings at the beginning and at the end of the project. The first to create relationships and trust, and the second to summarize experiences as well as ensure that everybody can look each other in the eye [35], [97], [110], [112].
- The project manager should travel to all distributed sites and keep closest to the sites where task coupling is high and group cohesion low [99].
- Plan meetings using a simple- or double rhythm. Using simple rhythm, meetings are held at a specified interval. Double rhythm consists of one meeting at project startup and another midway to summarize problems [73].

Develop liaisons between sites

- Use liaisons to facilitate information exchange, identify expertise, mediate cultural conflicts, and settle disputes [5], [12], [24], [34–36], [56] [WS1].
- If the organization consists of a main site and several sub sites: Let liaisons from the sub sites spend the startup phase at the main site to gain insight and overview of the project [5].
- Include travel expenses in the overall budget and do not perceive them as additional costs [WS1] [34].

Adopt shared reward systems

- Deploy evaluations and reward structures, which encourage group related behavior, to create cohesion - individual rewards are not advised [10], [30], [64], [108], [109] [WS1].

*Technical Integration***Increase technical compatibility between sites**

- Ensure that sites are technically compatible [22], [37].
- Choose sites where it is possible to maintain high quality transmissions at low cost considering parameters such as the country's technological infrastructure and different laws and regulations [10], [22], [46].
- Make international support contracts with sub contractors to ensure access to support at all sites [5].

Standardize and train in methods across sites

- Establish technical standards and stick to them to maintain project integrity [25].
- Introduce shared guidelines for error handling, accessibility to other group's documentation, and documentation for tests and testability [40].
- Use a shared tool that allows for tracking of corrections and bugs in all parts of the distributed organization [5].
- Standardize tools, methods and processes to create a harmonious and efficient project organization [24], [25], [56], [99].
- Such standardization implies training of participants and lower initial efficiency as experience with the chosen methods varies [5], [25], [46]. In the long run higher efficiency and fewer misunderstandings are expected [24], [56].
- Combine with: *Combine waterfall model and prototyping* [99].

Adopt appropriate communication technologies

- Include the country's infrastructure and bandwidth possibilities when considering choice of communication technology [10], [22], [46].
- Choose rich media if participants belong to a high context culture, where message interpretation relies heavily on contextual information. If participants belong to a low-context culture, leaner media can be used [88].
- Include speed and quality in the communication media requirements as well as stability and reliability [17], [22], [46], [116].
- Choose ICT that supports a suitable atmosphere for creation of trust, e.g., videoconferences can reduce the sense of physical and psychological distance [44].

- Support creativity by choosing ICT that supports a decentralized communication network, e.g., instant messaging [36], [97], [101].
- Utilize videoconference or telephone conference in addition to group support systems usage, whenever the group is working on a decision making task [19].
- Use telephone- and videoconferences to support relationship building [64].
- Consider cultural preferences when choosing ICT [88].
- Choose as rich media as possible to support social processes, collaboration, and cohesion [1], [30], [47], [86], [110], [111].
- Choose lean media, such as e-mail, for simple messages to reduce noise in the information. For complex and debatable information, choose richer media [68], [110].
- If the project has a large distribution over time zones: Consider asynchronous media [97].
- Larger projects (in terms of number of participants) should adopt communication technology that supports coordination and logistics, whereas smaller projects should choose technology that supports collaboration and communication [9].

Improve collaboration and communication technology skills

- Focus on strengthening the participants' collaboration and communication skills [5], [30], [46], [91], e.g., training in a wide variety of technologies [10], [46], [91].
- Use ICT training to enhance the use of lean media and thereby making them richer [111].
- Train participants in sharing contextual and social information [68], [91].

Improve development technology skills

- Educate and train in software development technology [22], [46], [100], especially participants being introduced to new technology [46], [56].
- Standardize training across sites [91], [100].

Handle differences in methods between sites

- The alternative to standardization: Manage differences by taking advantage of existing expertise, create fast results, and avoid expenses from training and adaptation to new methods [5], [25], [100].
- Communicate knowledge of methods and processes deployed by other groups and enhance understanding of strengths and weaknesses [100].
- "Capability Maturity Model" (CMM) can be used to ensure equal quality level of the deferring methods [25].
- Combine with: *Divide Tasks Systematically Between Sites and Reduce Coupling Between Sites* [5].

Combine waterfall model and prototyping

- Combine the waterfall model and prototyping, using prototyping to determine requirements and the waterfall model to maintain modularity, low task coupling, and structure in the process [99].

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