THE INFLUENCE OF TEAMWORK QUALITY ON SOFTWARE DEVELOPMENT TEAM PERFORMANCE

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ABSTRACT

Research has shown that software quality, to a large extent, is dependent on good teamwork (Hoegl & Gemuenden, 2001; Liang *et al.*, 2012; Henderson & Lees, 1992). Since the success rate of software development projects is low (The Standish Group, 2009), it is important to understand which factors of software development teams that have a significant influence on performance.

This thesis develops a model that extends the work of Hoegl and Gemuenden (2001). Based on the Teamwork Quality (TWQ) model, general sociological research literature, and several arguments that question the selection of teamwork quality factors by Hoegl and Gemuenden (2001), a new TWQ model is developed and evaluated. The six TWQ factors, i.e. communication, coordination of expertise, cohesion, trust, mutual support, and value diversity, are described.

The research goal is to verify if a model that includes trust, value diversity, and coordination of expertise contributes more to explaining project success than the factors of Hoegl and Gemuenden (2001) alone. Hypotheses regarding the relationship between TWQ and team performance and the improvement of the model are tested using data from 252 team members and stakeholders from 28 Dutch and one Ukraine software development teams.

Results from structural equation modeling analyses show that teamwork quality is significantly related to team performance, rated by both team members and stakeholders. The magnitude of this relationship differs with the perspective of team performance as rated by team members and as rated by stakeholders.

The main contribution of this thesis is the significantly stronger support for the notion that better teamwork creates better software than previous research has found. Compared to the original TWQ model (Hoegl & Gemuenden, 2001), in the new model TWQ explains 40% more of the variance of team performance as rated by team members and more than 50% more as rated by stakeholders. However, the generalizability of our results and the comparability of our model to that of Hoegl and Gemuenden's (2001) is not optimal. Finally, limitations of our study and ideas for future research are discussed.

FOREWORD

This thesis is written as completion to the master Business Communication and Digital Media at Tilburg University. This thesis is intended to improve the success of software development projects by providing more insights into the role of social (team) factors of software development.

When I got the opportunity to do research into the relationship between teamwork and team performance in software development teams at the Software Improvement Group (SIG), I immediately was enthusiastic. Having rowed at a top sports level for five years, I have great interest in group dynamics. SIG is a management consultancy that focuses on software related challenges. SIG provides management with a fact-based insight into their current IT situation, along with razor sharp, pragmatic and highly actionable recommendations on how to improve on that situation.

SIG noticed divergence in software quality among software development teams. Even though the core business of SIG is translating detailed technical findings concerning software systems into actionable advice for upper management, the question was raised to what extend software quality depends on social (teamwork) factors. To me, the combination SIG's knowledge and expertise and my social sciences research background have made this research project a success.

Since November I have been working on this research topic. I have experienced this period as very pleasant and instructive. I would like to thank my supervisor from the university, Aske Plaat, for his support, patience, and feedback. Also, I would like to thank Ariadi Nugroho and Joost Visser from SIG for their guidance, critical view, and for giving me the unique opportunity to write and present a scientific paper at the EASE 2013 conference in Brazil. Furthermore, I would like to thank Martijn Goudbeek en Alex Schouten for helping me with the statistics analyses. With the help of the Aske Plaat, SIG and the EQuA Project, I have been able to collect a great amount of participants and achieve a result I am very pleased with. Finally, I would like to thank my family and friends for their endless support and faith.

Emily Weimar Tilburg, June 2013

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1. INTRODUCTION

Software quality was shown to be dependent on good teamwork (Hoegl & Gemuenden, 2001; Liang, Wu, Jiang & Klein, 2012; Henderson & Lee, 1992). Reported statistics by The Standish Group (2009) have shown a low success rate of 32% of information system development projects; 44% of the projects surpassed the planned budget and time; and 24% of the projects failed completely. Since software development is primarily a team effort (Faraj & Sproull, 2000), it is important to understand the factors or characteristics in software development teams that have significant influences on team performance. This knowledge can be very useful to promote project success.

Teamwork has been considered a crucial success factor of software development projects in the theoretical literature (Cooper, 1993; Pinto, Pinto & Prescott, 1993; Gemuenden, 1990; Griffin & Hauser, 1992). However, in previous works, Hoegl and Gemuenden (2001) identified the lack of empirical evidence regarding the importance of teamwork for the success of innovative teams in previous works. They present two main points of critique: (1) previous research did not address the multifaceted nature of teams but studies rather focused on the relationship between team-based organizations and performance (Gupta, Ray & Wileman, 1987; Hise, O'Neal, Parasuraman, & McNeal, 1990; Cooper & Kleinschmidt, 1995); and (2) there are conflicts in the literature about the impact of teamwork on team success (Thamhain & Kamm, 1993; Campion, Medsker & Higgs, 1993; Cohen, Ledford & Spreitzer, 1996). In order to address these issues, Hoegl and Gemuenden (2001) studied the influence of six teamwork quality (TWQ) factors – *viz.* communication, coordination, balance of member contribution, mutual support, effort, and cohesion – on the success of innovative projects. They based their model on the fundamental idea that the success of teams depends on the degree to which team members are able to collaborate. The results were promising; the TWQ factors were significantly correlated with performance ratings. However, TWQ only explained 41% of the variance of team member ratings, 11% of team leader ratings, and 7% of the manager ratings.

Hoegl and Gemuenden (2001) gave arguments for the reason why their model did not explain a larger portion of project success. They argue that teamwork quality is not the only determinant for project success. Other factors such as management, organizational factors and communication between the team and external sources might also play a role in determining project success. However, we have reasons to think that their model is not all-encompassing and there is room for improvement. Trust, for example, is found to be a key predictor for team performance (Friedlander, 1970) and an important support mechanism for teamwork (Bandow, 2001; Salas, Sims & Burke, 2005), but it is not part of Hoegl and Gemuenden's (2001) model. Also, Hoegl and Gemuenden (2001) measured team uniformity related to work norms concerning effort. We argue that effort is one of the multiple facets of work norms. Therefore, we propose to use a more generic measure of work norms, including uniformity of values, goals and beliefs. Hence, covering norms about effort. Based on our study of the sociological research literature, we propose to improve and extend the model with other teamwork quality factors.

1.1 PROBLEM STATEMENT AND GOAL OF THE RESEARCH

The purpose of this study is to examine the factors within software development teams that have significant influence on their performance to accomplish tasks. It is important to get more knowledge on this topic since a lot of time and money is being invested in software development. However, the success rate of software development projects is disappointing (The Standish Group, 2009). The focus of our study is on the quality of interactions within software development teams. Based on the TWQ model (Hoegl & Gemuenden, 2001) (Figure 1), sociological research, and several arguments that question the selection of teamwork quality factors by Hoegl and Gemuenden (2001), a new model is developed.

The proposed new teamwork quality model includes the following teamwork quality factors: communication, coordination of expertise, cohesion, trust, mutual support, and value diversity (Figure 2). The goal of the research, therefore, is to validate of the following assumption holds:

A model that includes trust, value diversity, and coordination of expertise contributes more to explaining project success than the factors of Hoegl and Gemuenden alone.

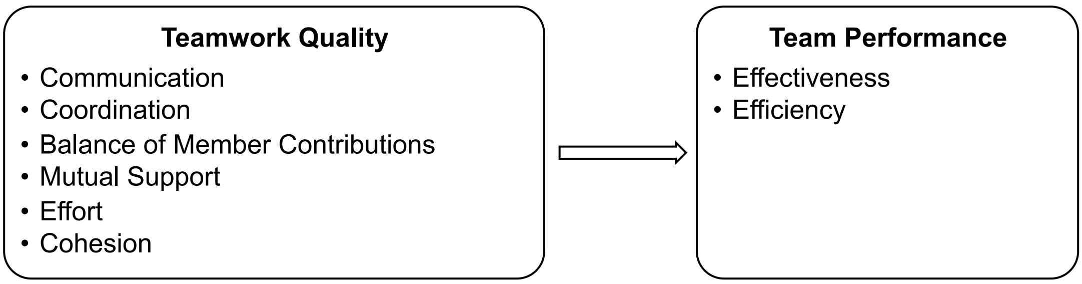


Figure 1. *Original TWQ model of Hoegl & Gemuenden (2001)*

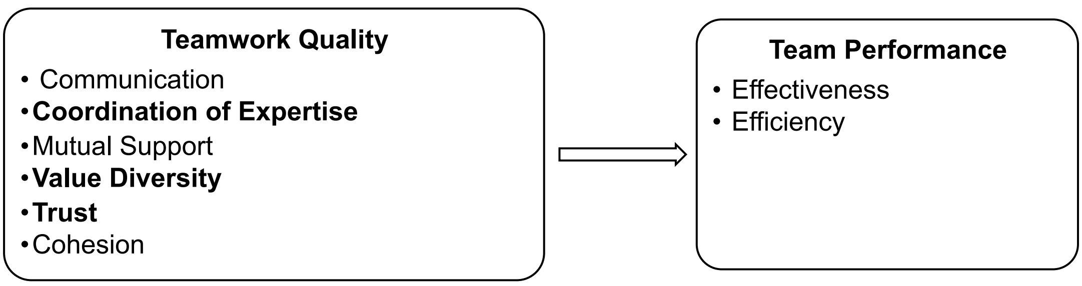


Figure 2. *New TWQ model (2013)*

Based on the goal of the study, we arrive at the following research questions:

1. *How is Teamwork Quality related to the success of software development projects?*
2. *How does the new TWQ model perform with respect to the original model of Hoegl and Gemuenden (2001)?*

1.2 APPROACH

In order to answer these research questions, we tested the teamwork quality model with 29 software development teams from 18 companies and compare the results with the performance of the teams in achieving their goals. All the team members that have a direct contribution to the development of the software, from the analysis to the testing phase, were asked to participate in the study. Project performance was measured by collecting data from both team members and project stakeholders about the success of the team on different measures (i.e. quality, schedule, costs, and morale). We then (1) statistically analyzed the relationship between team characteristics and team performance, (2) compared the explanatory power of the new model with that of Hoegl and Gemuenden (2001), and (3) tried to explain potential differences in explanatory power of the models.

1.3 SCOPE OF RESEARCH

In their study, Hoegl and Gemuenden (2001) focused on innovative projects. We focus specifically on the quality of interactions within software development teams. This is based on the fundamental idea that the success of a team depends on the quality of interaction or collaboration between team members. As proposed by Hoegl and Gemuenden (2001), the quality of interactions between team members in teams is captured in the construct TWQ. Six TWQ factors are integrated in the concept of TWQ, encompassing the collaboration of team members working together. Both task-related and social interactions within the team are covered. Since the focus is on the quality of interactions within the team, the quality of interactions with external parties such as management, clients or other teams is out of the scope of the current study.

Furthermore, factors such as the content of the tasks and activities are also excluded from our study. As Hoegl and Gemuenden (2001) explain, the TWQ model is concerned with the quality of communication on task-relevant information and not with the content of the information. Therefore, both leadership activities such as planning, organizing, motivating and performance assessments (Bandow, 2001) and issues of managerial control (Henderson & Lee, 1992) are out of scope. Since the focus is on the team level, individual and environmental level factors such as attitudes, personality, group-task characteristics and environmental stress (McGrath, 1964) are not taken into account. Additionally, we are aware of the fact that even though people have to work as a team, reward structures might be individual and may influence work group effectiveness and (negatively) affect team-based problem solving (Hackman, 1990; Kerrin & Oliver, 2002). Our study focuses on the team so the balance between personal and team ambitions or incentives is not covered. Even though the above-mentioned factors might influence TWQ or are facilitated by high TWQ, they are not examined in the present study. Future studies might investigate the influence of these factors. However, we focus on improving the TWQ model and maintain the scope of Hoegl and Gemuenden (2001).

1.4 RELEVANCE OF RESEARCH

The expected contributions of this work are as follows: (1) we perform an independent verification of some of the factors of the TWQ model of Hoegl and Gemuenden (2001); (2) we extend the model with factors such as trust for which we have indications that they are important for software projects; (3) we validate our more encompassing model by measuring the relationship between the various aspects of teamwork and performance.

Results of this work will have the following practical implications. If we can identify what teamwork factors contribute to higher performance, software managers will be able to use this knowledge to build and manage teams more constructively. Self-organizing teams (as prevalent in Agile software development) will be able to use this knowledge to enhance their performance (Cockburn & Highsmith, 2001).

1.5 STRUCTURE

The rest of the thesis is structured as follows. In section 2, we will provide the theoretical background for the new conceptual TWQ model, which includes a critique on the teamwork quality factor selection of Hoegl and Gemuenden (2001) based on a study of the general sociological research literature. In section 3, our research method for testing the model will be described. Section 4 will present the results of our study. These results will be discussed in section 5 together with the implications and limitations of the study and ideas for future research. Section 6 and 7 will provide a summary and conclusion of the thesis.

2. THEORETICAL FRAMEWORK

In this chapter, we will first elaborate on the definitions of teams, teamwork and performance. Second, we will discuss the TWQ factors (Table 1) and their relationship or contribution to the complete TWQ model, based on current scientific literature on teamwork, software development and team performance.

2.1 TEAMS, TEAMWORK AND PERFORMANCE

Over the past decades, multiple studies on teamwork have been executed. In their literature review, Salas, Stagl, Burke, & Goodwin (2007), reviewed more than 130 models and frameworks of teamwork or a component of it. These include models at different levels of teamwork. Some of the teamwork models in the field are more general models of teamwork (e.g. Salas et al., 2005), some are more context-specific (e.g. Jeffcott & Mackenzie, 2008), others focus more on specific team processes (e.g. Chow & Cao, 2008), and there are models that focus more on the individual level of teams (e.g. Siau, Tan, & Sheng, 2010). However, all of these models are based on different general concepts of teams.

Following Hoegl and Gemuenden (2001), a *team* can be defined in terms of its (1) context, a social system that is embedded in an organization, (2) identity, members of the team are perceived to be a member of the team by themselves and by the others, and (3) teamwork, members work together on a common task. To accomplish their common goals, team members must work together. Each member of a team has a specific role and specific *individual taskwork*. This is the individual activity of a team member that does not require interdependent interactions with other member of the team. *Teamwork*, on the other hand, is the activity of multiple interdependent individuals (Salas, Cooke, & Roosen, 2008). It is a set of interrelated components of performance that are needed to efficiently and successfully facilitate coordinated and adaptive performance (Salas et al., 2008; Cannon-Bowers

Table 1

Teamwork quality factors

Communication. There is sufficient, frequent, spontaneous, timeliness, precise and useful exchange of information.
Coordination of Expertise. Location and need of expertise are known and coordinated.
Cohesion. Team members are motivated to maintain the team and there is team spirit.
Trust. Team members trust each other.
Mutual Support. Team members help and support each other in carrying out their tasks.
Value Diversity. Team members share the same values and goals.
Team Performance. The degree to which the project team completes the project efficiently and effectively.

Tannenbaum, Salas, & Volpe, 1995; Salas, Bowers, & Cannon-Bowers, 1995; Baker, Gustafson, Beaubien, Salas, & Barach, 2003). Both taskwork and teamwork, even though they are distinct components, are important for teams to be effective in complex situations (Morgan, Glickman, Woodward, Blaiwes, & Salas, 1986). The multilevel process that arises when team members are involved in managing their individual task- and teamwork and the teamwork processes, is defined as *team performance* (Kozlowski & Klein, 2000).

Team performance can be assessed in terms of effectiveness and efficiency. *Effectiveness* is the degree to which a team meets the expectations of the quality of the outcome (Hackman, 1987). This refers to, for example, the degree to which the goals and quality of the project were met. *Efficiency* refers to the degree to which the team met time and budget objectives (Hoegl & Gemuenden, 2001). Effectiveness, therefore, concerns the comparison between actual and intended *outcome*, and efficiency refers to the assessment of the actual inputs compared to the intended *inputs*.

2.2 Selection of Factors

We chose the TWQ model of Hoegl and Gemuenden (2001) as a basis for our study since we consider their study prominent, being cited by others regularly. There are several arguments, however, to question Hoegl and Gemuenden's (2001) selection of TWQ factors. First, trust is excluded while this is a key predictor for team performance (Friedlander, 1970). Second, Hoegl and Gemuenden (2001) argue that especially norms about the effort of team members are important for TWQ. However, we think that measuring norms about effort does not provide enough coverage. Norms about effort are only part of all team norms and values; there are other norms and values that are important too. For example, shared goals or beliefs about manners can be part of discussion. Therefore we instead propose to use a generic or higher-level measure of value diversity that covers all norms and values, both norms about the effort as other team norms and values. Third, balance of member contributions measures whether contributions to the team are balanced in terms of member's specific knowledge and experience. We believe that Faraj and Sproull's (2000) measure of coordination of expertise is a broader measure. Faraj and Sproull's measure of coordination of expertise incorporates (1) whether and where expertise is located within the team, (2) if the team recognizes any need for expertise, and (3) if expertise within the team is brought to bear. Therefore, this measure covers both the factor of coordination and balance of member contributions Hoegl and Gemuenden (2001) use in their study.

In the next section, we will elaborate more on the different factors. We will discuss how each factor relates to team performance and why we chose to incorporate each factor in our model.

2.3 TEAMWORK FACTORS

2.3.1 COMMUNICATION

It is broadly recognized that communication is a fundamental component of teamwork. It provides a mean to exchange information, share ideas among team members, coordinate efforts and provide feedback (Pinto & Pinto, 1990). Not only is the exchange of information important, even more important is that the information is delivered to the right person and interpreted in the way the sender intended to (Pinto & Pinto, 1990; Brodbeck, 2001; He, Butler & King, 2007). Lu, Xiang, Wang and Xiaopeng (2010), for example, found that a lack of communication or the existence of misunderstanding between team members and stakeholders of a project are two main causes of project failure. Also other studies recognize the importance of communication for project success (i.e. Katz & Allen, 1998; Griffin & Hauzer, 1992).

Hoegl and Gemuenden (2001) describe the quality of communication within a team in terms of the frequency, formalization, structure, and openness of the information exchange. *Frequency* describes how extensively team members communicate; it considers how much time team members spend communicating with each other. The *degree of formalization* refers to the spontaneity of communication. Formal communication occurs when a large amount of preparation and planning is needed prior to the communication to occur, such as scheduled meetings. Informal communication includes spontaneous contacts such as talks during a coffee break, short phone calls and brief chat conversations. This informal communication can be of great importance for software development teams, since it allows team members to share ideas and discuss problems more quickly and efficiently. Furthermore, the *structure* of communication is important for software development teams. Team members should be able to communicate directly with each other, since communication though a mediator is vulnerable for miscommunication and is time consuming. Furthermore, the *openness* of information exchange is important (Gladstein, 1984; Pinto & Pinto, 1990). It is crucial that team members are open to each other and not hold back important information, since this can harm the integration of team members' knowledge and experience. Being one of the most fundamental functions of teamwork (Hoegl & Gemuenden, 2001).

Moreover, communication provides a basis for other factors that determine team performance. For example, communication is needed to coordinate team member's efforts and knowledge (Han, Lee & Seo, 2008). Furthermore, it is needed for a team to understand the collective missions (O'Connor, 1993), to be sure the team shares the same mental model continuously (Salas, Cannon-Bowers & Johnston, 1997), and to facilitate trust within a team (Jarvenpaa & Leidner, 2006). Communication can thus be seen as a primary tool that is needed to create a high-performing team. Therefore, we decided that communication should be part of the TWQ model.

2.3.2 Coordination of Expertise

Hoegl and Gemuenden (2001) argue that coordination is an important aspect of teamwork. It refers to the development and agreement of a team of a common task-related goal structure, with well-defined subgoals for each member, without any gaps or overlaps. Since software development is knowledge work, expertise is an elementary resource, which is not considered in the study of Hoegl and Gemuenden (2001). Coordination of expertise refers to the "management of knowledge and skill dependencies" (Faraj & Sproull, 2000, p. 1555). This includes knowing where expertise is situated within a team, recognizing the need for expertise, and bringing expertise to good use.

Knowing where expertise is located means knowing where the answer to a problem is located and who has the skills an/or knowledge to do certain tasks. Knowing expertise location can help to assign tasks to the members of the team (He et al. 2007). Team performance has shown to increase when team members know how expertise is distributed among the members of the team (Hinsz, Tindale, & Vollrath, 1997; Lewis, 2003). When team members know where expertise is located, they can better anticipate rather than react on other's behaviors (Murnighan & Conlon, 1991). Therefore, it is important for software development teams to know where expertise is located within the team. However, this expertise cannot be brought to good use when you do not know when and where certain expertise is needed. The *need for expertise* might be higher at different times in the project, but it is important that all team members know who has which expertise and who needs what expertise at certain times. If software development team members recognize the need of expertise, they can anticipate by supporting each other with their expertise, or get the needed expertise from outside when this is needed. In this way, processes can be carried out effectively and efficiently. Yet, knowing where expertise is located and recognizing when expertise is needed is not enough to perform well as a team. Expertise can only be *brought to good use* when the team has developed a timely manner by which they can make good use of the expertise available within the team. Team members should share their knowledge and expertise though emerging informal interactions (Nonaka & Takeuchi, 1995). Teams will develop a collective mind when they are aware of how the work of one team member contributes to the tasks of another member of the team (Weick & Roberts, 1993). This, in turn, will lead to better coordination (Crowston & Kammerer, 1998).

Faraj and Sproull (2000) found a significant positive relationship between coordination of expertise and team performance. This relationship was stronger than the relationship between (merely) the presence of expertise and performance. Hoegl and Gemuenden (2001) included coordination and balance of member contributions in their TWQ model. Coordination refers to the degree to which individual efforts are well structured and synchronized within the team, while balance of member contributions considers the degree to which team members are able to bring their expertise to their full potential. Faraj and Sproull's (2000) measure of coordination of expertise, to a certain degree, is a combination of Hoegl and Gemuenden's (2001) measures of coordination and balance of member contributions, supplemented with the link to expertise. Since software development is knowledge work, we consider the link between coordination and expertise to be important. Therefore, we decided to use Faraj and Sproull's (2000) measure of coordination of expertise instead of Hoegl and Gemuenden's (2001) measures of coordination and balance of member contributions.

2.3.3 COHESION

Cohesion is defined as "an individual's sense of belonging to a particular group and his or her feeling of morale associated with membership in a group" (Bollen & Hoyle, 1990, p. 482). Cohesion, here, consists of two dimensions: (1) a sense of belonging and (2) the feeling of morale. Without a sense of belonging, team members would not like to associate with the rest of their team, and without a sense of morale, they would not be motivated to achieve organizational goals and objectives. Three forces of cohesion were distinguished by Mullen and Copper (1994), namely: (1) interpersonal attraction of team members, (2) commitment to the team task, and (3) group pride-team spirit.

Cohesion was found to be an important antecedent for team performance (Carron, Widmeyer, & Brawley, 1985). Without a sense of belonging and a desire to stay on the team and keep it going, high quality teamwork seems improbable (Hoegl & Gemuenden, 2001). Especially when the team task required high coordination and communication, hence, software development, cohesion was found to be important (Gully, Devine, & Whitney, 1995).

However, Mullen and Copper (1994), in their meta-analysis, revealed disagreements about the relationship between group cohesion and performance in literature. They conclude that the relationship between cohesion and performance is significant but small. Chang and Bordia (2001) assign the disagreement in literature to the inconsistency in measurements and definitions of cohesion and performance. They postulated that consistency in the definition and measurements of cohesion and performance was needed to give a more decisive answer. Based on the multidimensional model of Carron, Widmeyer, & Brawley (1985), Chang and Bordia (2001) studied the relationship between group cohesion and performance. A direct relationship between specific dimensions of group cohesiveness and performance was found. Cohesion was indicated to be an antecedent of performance (and not a consequence of it).

Despite of different authors having different opinions, we consider and expect cohesion to be an important teamwork quality factor for software development teams. An adequate feeling of togetherness and belonging seems needed to achieve high quality collaboration.

2.3.4 TRUST

Friedlander (1970) found that trust is a key predictor for team performance. There are many different definitions of trust. Trust is seen as the degree to which someone believes his team members are dependable (Pearce, Sommer, Morris, & Frideger, 1992), is willing to be vulnerable to the action of others (Mayer, Davis, & Schoorman, 1995), cares about the group's interest (Dirks, 1999), or is competent (Mishra, 1993). Following Mayer et al. (1995), we define trust as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other will perform a particular action important to the trustor, irrespective of the ability to monitor or control the other party".

Trust influences many team processes such as the willingness to share information, give substantial feedback and manage time correctly (Bandow, 2001). Team members communicate more openly and share information more freely when they trust their team members or feel trusted by others. When they have the feeling their contribution is not appreciated, the chance is higher that they will not share information (Boss, 1978; Zand, 1972; Jones & George, 1998; Bandow, 2001). Additionally, trust has a positive effect on satisfaction of communication, the perceived accuracy of information given (Roberts & O'Reily, 1974), and satisfaction of working with the group (Ward, 1997).

Furthermore, trust fosters the way team members interpret others' behaviors such as performance monitoring (Salas et al., 2005). When there is a lack of trust within a team, team individuals will spend more time checking upon others and inspecting each other, instead of working together as a team to produce value-adding ideas (Cooper & Sawaf, 1996). Moreover, they are more likely to interpret ambiguous behaviors or actions of others, such as missing deadlines, as purposely damaging actions against the individual or the team (Creed & Miles, 1996). Handy (1995) indicated the risk of a self-fulfilling prophecy to occur when team trust is low; team members might not see why they should be trustworthy if they have the feeling that they are not being trusted by others anyway. Team trust is thus needed to create a climate in which team members accept and understand that other members keep an eye on them, serving the greater good of the team (Salas et al., 2005).

Given the importance of trust as a supporting mechanism for teamwork, we argue that this factor cannot be eliminated. In light of the scientific evidence of the relationship between trust, (other factors of) TWQ and team performance, we decided to include trust in our TWQ model.

2.3.5 MUTUAL SUPPORT

According to Tjosvold (1995), mutual support is an essential element of TWQ. The idea of teamwork, namely, is based on the idea of mutual support of the team members rather than the competition between them (Hoegl & Gemuenden, 2001). Competition between people can exert a positive influence on the motivation and performance of individual tasks. For interdependent tasks such as software development, however, cooperation or mutual support amongst team members is more important. Team members working on a shared goal should try to support instead of trying to outdo each other. They should show respect, give help and support when needed, and stimulate ideas of other team members and develop them further. If, on the other hand, team members demonstrate competitive behaviors, this can lead to distrust and frustration within the team (Tjosvold, 1995). Both quality and acceptance of ideas generated by members of the team increase when members cooperate (Cooke & Szumal, 1994). Mutual support, therefore, is an important element of teamwork and needed to be able to reach team goals. The better team members support each other, the more effective and efficient these goals can be reached.

2.3.6 VALUE DIVERSITY

Different types of team diversity exist (e.g. informational, social category and value diversity). With each type of diversity, different types of challenges and opportunities are involved. Each has a different influence on team performance (Jehn et al., 1999). When people refer to team diversity, most often they refer to social category diversity (McGrath, Berdahl, & Arrow, 1996). It concerns differences in social differences such as age, gender, race, and ethnicity (Pelled, 1996). Since the focus on the current study is on team collaboration, instead of team composition, we focus on value diversity. Value diversity arises when team members have a different perspective on the team’s task, goal, or mission. Such differences can lead to relationship, task, or process conflicts (Jehn, 1994; Jehn et al., 1999). For example, team members who value quality are likely to get into conflict with members who value efficiency about the allocation of resources or about the mission of the team – either producing high quality products or a high amount of products. Since software development is a complex process in which team members are interdependent, good interaction among team members is important (e.g. communication, coordination, mutual support). High value diversity, therefore, can have a negative influence on team interaction. When team members share the same values, on the other hand, relationship conflicts among team members are likely to decrease (Jehn, 1994). Hackman (1990) postulates that when team members share the same values and goals, interpersonal relationships are enhanced. Low value diversity, therefore, enhances teamwork. In addition to influencing teamwork, value diversity also influences team performance. Low value diversity is needed to be efficient, effective and sustain a high moral within the team (Jehn et al., 1999).

Hoegl and Gemuenden (2001) argue that especially norms about the effort of team members are important for TWQ. However, effort is only one of the multiple facets team members might have shared expectations about. Value diversity regards the team goal and mission, which is on a higher order than effort. Hence, when team members share the same mission or vision, it is likely that they will prioritize the task of the team and have the same ideas regarding work norms too. Therefore, we propose to use a more encompassing measure of value diversity instead of the more specific measure of effort Hoegl and Gemuenden (2001) used.

2.3.7 PROJECT PERFORMANCE

A measure of performance is needed to identify the value of production and teamwork. In our study, we use an objective measure of team performance, making it difficult to define success. Because of the different interests of the parties that are involved with the software development projects, the perception of project success can differ. If one perceives a project to be a success or failure, it does not imply that another has the same interpretation of success. Members of software development teams, for example, usually relate project success to the completion of the scope of the project. While external stakeholders usually use measures of target time and costs to assess project performance (Agarwal & Rathod, 2006). Evaluations of project performance, therefore, can vary across team members, team leaders and stakeholders, making it hard to measure team performance objectively. Even though the subjectivity of performance measures remains a disputed topic, multiple measures of performance can be found in literature. Hoegl and Gemuenden (2001) emphasize the importance of multiple ratings of team performance, coming from sources both internal and external to the team to improve objectivity.

Software development has been measured in multiple ways (Delone & McLean, 1992, 2003; Petter, DeLone & McLean, 2008). Nevertheless, two central aspects of project success can be observed: efficiency and effectiveness (as discussed in section 2.1). Team performance is the ability of a software development team to attain the desired level of costs, time and product quality. Effectiveness, hereby, refers to the degree to which a team meets the expectations of the quality of the outcome (Hackman, 1987). Efficiency reflects the degree to which the team met time and budget objectives (Hoegl & Gemuenden, 2001). Together, efficiency and effectiveness determine project success. Project management (i.e. efficiency) influences product quality (i.e. effectiveness), however, a product can be of good quality regardless of poor project management and vise versa.

So, software development projects can be described as successful when a product with the desired level of quality is delivered within the pre-determined time and cost limits (Agarwal & Rathod, 2006). It is important to pre-determine project requirements (i.e. quality, time and costs) and assessment criteria to reduce ambiguity and subjectivity about the definition of success. Furthermore, it is important that these goals and assessment criteria are communicated well among the different parties that are involved (Wateridge, 1995). Project performance, consequently, can be measured by measuring at the assessment of project success by the different parties involved.

2.4 HYPOTHESES

Based on the conceptual model and the literature that has been discussed, two main hypotheses are formulated.

Hypothesis 1: Higher teamwork quality corresponds to higher team performance. Based on the TWQ model of Hoegl and Gemuenden (2001) and an extensive literature study, we created a new TWQ model. All TWQ factors seem to have an influence on TWQ and team performance. We expect the six TWQ to show high interdependence. Where trust, for example, fosters open communication (Boss, 1978; Zand, 1972; Jones & George, 1998; Bandow, 2001), is communication needed to coordinate team member's efforts and knowledge (Han, Lee & Seo, 2008). Together, we expect the six TWQ factors to contribute to the same latent construct (i.e. TWQ). Like Hoegl and Gemuenden (2001), we expect to find a positive relationship between TWQ and team performance. Since software development primarily is a team effort (Faraj & Sproull, 2000) and teamwork has been considered a crucial success factor in theoretical literature (Cooper, 1993; Pinto, Pinto & Prescott, 1993; Gemuenden, 1990; Griffin & Hauser, 1992), we expect the chance of high team performance to increase when teamwork quality increases.

Hypothesis 2:The new Teamwork Quality model has a higher explanatory power than the original model of Hoegl and Gemuenden (2001). Hoegl and Gemuenden (2001) found TWQ to explain 41% of the variance of team performance as rated by team members, 11% as rated by team leaders, and 7% as rated by managers. Suggesting our model is an improvement of their model; we expect to find higher explanatory powers than Hoegl and Gemuenden (2001). Hoegl and Gemuenen excluded trust, while this is a key predictor for team performance (Friedlander, 1970). Second, Hoegl and Gemuenden (2001) argue that especially norms about the effort of team members are important for TWQ. However, we think that measuring norms about effort does not provide enough coverage. Therefore we use a more generic or higher-level measure of value diversity instead, that covers all norms and values, both norms about the effort as other team norms and values. Third, balance of member contributions measures whether contributions to the team are balanced in terms of member's specific knowledge and experience. We believe that Faraj and Sproull's (2000) measure of coordination of expertise is a broader measure, covering both the factor of coordination and balance of member contributions Hoegl and Gemuenden (2001) use in their study. Based on these arguments we expect our model to give a better prediction of software development team performance than Hoegl and Gemuenden's (2001) model.

3. STUDY DESIGN

The main purpose of this study, as described in Chapter 1, is to examine the factors within software development teams that have significant influence on their performance to accomplish tasks and to verify our assumption that our TWQ model is better in explaining team performance than that of Hoegl and Gemuenden (2001). This chapter focuses on the methods used to execute this empirical study. First, the hypotheses will be discussed. Consequently, the methods used to collect data and test the hypotheses will be described and motivated.

3.1 STUDY DESIGN

In this empirical study, the relationship between TWQ and team performance as rated by team members and stakeholders was investigated. Both qualitative and quantitative data were gathered by means of a fully standardized, non-randomized, online questionnaire.

Two groups of participants were distinguished: team members and stakeholders. Stakeholders are not formal members of the team but are directly affected by the output of the team. These include, for example, project sponsors or managers who were responsible for the production and implementation of the information system. First, participants were asked to identify the team being evaluated, assuring all respondents corresponding to one team were referring to the same set of individuals as a team (Part 1). Team members were then asked about characteristics of themselves, the team and the project (Part 2). Consequently, questions measured the quality of teamwork and team performance (Part 3-9). Finally, two open-ended questions allowed participants to give comments or remarks (Part 10). Stakeholders were only asked to identify the team (Part 1), assess its team performance (Part 9), and were allowed to give additional remarks at the end (Part 10). The complete questionnaire for team member can be found in Appendix A and for stakeholder in Appendix B. The questionnaire consisted of the following parts:

- Part 1. Identify organization and team.
- Part 2. Demographic data about the participant, the team, and the project.
- Part 3. Quality of communication.
- Part 4. Evaluation of mutual support within the team.
- Part 5. The level of cohesion.
- Part 6. Evaluation of the level of trust within the team.
- Part 7. The level of team diversity.
- Part 8. Assessment of coordination of expertise.
- Part 9. Evaluation of team performance.
- Part 10. Open-ended question(s) giving space for comments and remarks.

All team members were asked to participate. In a few cases it was not possible to reach all team members. In these cases, team managers/leaders were asked to provide a representative sample of the team. For each software development team one to six stakeholders filled out a questionnaire. One team did not manage to get a stakeholder rating of performance. Using multiple perspectives on project performance to obtain more reliable ratings of the team level factors was found to be effective by Hoegl and Gemuenden (2001) since performance ratings differed among the different parties (team members, team leaders and team managers).

We chose to use an online questionnaire because it is flexible, time-efficient and data can be easily entered and analyzed, reducing the risk of reliability errors. We tried to overcome potential disadvantages of online surveys such as the risk of being perceived as junk mail or impersonal, threatening privacy and security concerns of the respondents, the risk of a low response rate and the potential threat of unclear answering instructions by (1) conducting a test run and (2) by distributing the questionnaire via the project leaders (Evans & Mathur, 2005).

3.1.1 Data Collection

The goal was to gather as many software development teams as possible, with a minimum amount of 100 participants to be able to conduct statistical analyses. Based on an average team size of five, at least 20 software development teams were required to participate. Teams had to fulfill the following conditions: (1) it had to be a software development team (2) of at least three members (3) that is embedded in an organization (4) and whose members considered themselves to be a team. In terms of diversity, we tried to find a mix of development teams from the public and the private sector, with different core businesses. All targeted development teams belonged to the domain of business software products. Furthermore, we looked at diversity in terms of, for example, team size, development method, and main programming language used. Within each team, we hoped to find a mix of roles, experience and personal background.

Participation recruitment was done through snowball sampling, making use of our network to make contact with organizations to ask for their willingness to participate. The two main channels we used were the Dutch CIO Platform[1] and the network of the EQuA Project[2]. Through the CIO Platform, we recruited development teams from the public sector. Private sector development teams were reached via the EQuA project. Furthermore, we made use of

[1] http://www.cio-platform.nl
[2] http://www.equaproject.nl

the business contacts of SIG[3] to send out invitations for our study. All of these initial participation requests were done through email.

3.1.2 PROCEDURES

The study consisted of two main procedures:

1. Personal meetings with the team managers/leaders.
2. Online questionnaire distribution through the team managers/leaders.

Prior to sending out the questionnaires, personal meetings with all team managers/leaders were arranged. During these meetings, the background, objectives and procedures of the study were explained.

Consequently, each team manager/leader received two emails; (1) an email with instructions and a hyperlink referring to the online questionnaire for team members, and (2) an email with instructions and a hyperlink referring to the online questionnaire for stakeholders (Appendix C). Team managers/leaders were asked to distribute the corresponding email among the team members and relevant stakeholder(s). By asking the team managers to distribute the questionnaire, we expected that team members felt a higher commitment and motivation to fill out the questionnaire. Participation, however, was fully voluntary.

In an introducing text, respondents were thanked for their participation and informed about the topic of the study. Furthermore, anonymity and confidentiality was guaranteed and respondents were asked to complete the questionnaire in one go. Finally, the structure of the questionnaire was briefly explained. After this introduction, the questionnaire started.

The questionnaires were non-randomized so all questionnaires followed the same order. The first part included questions about the participant, the team and the project. Afterwards, questions measured the six TWQ factors and the level of team performance. Thereafter, open-ended questions allowed space for comments or remarks. Finally, participants were thanked for their participation.

Section 3.2.4 elaborates more on the measures for the different constructs. Filling out the team member questionnaire took each respondent about 10 to 15 minutes. Time consumption of the stakeholder questionnaire was approximately 5 minutes. The tool used to collect the data was ThesisTools[4], an online program that respondents can open in all browsers.

[3] http://www.sig.eu
[4] http://www.thesistools.nl

3.1.3 PARTICIPANTS

The study included two groups of respondents: (1) team members and (2) stakeholders. In total, 352 questionnaires were filled out; 204 team member questionnaires and 128 stakeholder questionnaires were filled out. Participants who quit halfway or did not complete the questionnaire were excluded for analysis. Participants who (sporadically) did not answer a question(s), but did complete the questionnaire were not excluded from the sample. A number of 199 team member responses were used for analyses. A total of 53 stakeholder responses were used for analyses. The other 75 responses were removed from the stakeholder sample because these concerned team members who filled out the wrong questionnaire due to a mistake made by their team leader; two team leaders sent the email with the hyperlink of the stakeholder questionnaire to the team members. After this was noticed, these participants were asked to fill out the correct (team member) questionnaire after all. The team members who gave answer to this request (N = 32) are included in the total of 199 team member responses. An overview of the participant distribution is illustrated in figure 3.

So, in total 252 valid participants were included in the study for analyses. These participants are divided over 29 teams from 18 Dutch organizations, representing different industries including business and finance, IT/ICT, high technology, and governmental/public institutions. Characteristics of the sample population can be found in table 2.

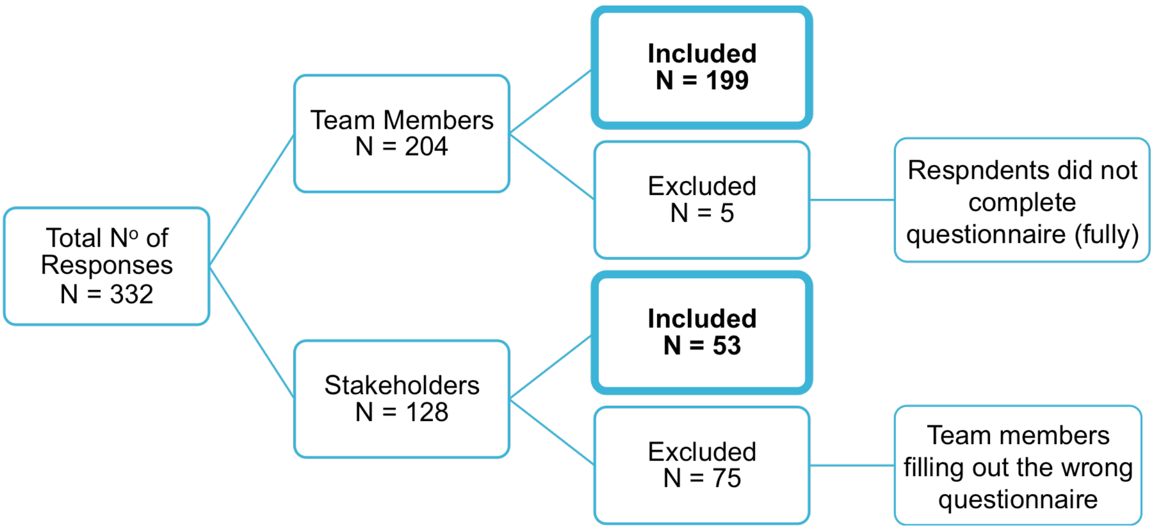
Participants included software team members (N = 199), of which 91.0% male (N = 181) and 9.0% female (N = 18), and project stakeholders (N = 53). The average age of the team members was 37.37 years (*SD* = 9.48). Most team members had an IT education (69.3%, N = 138), nearly a quarter a non-IT educational background (24.6%, N = 49), and the remaining 6.0% had another educational background (N = 12), for example a combination of IT and non-IT. Software development experience was more or less equally divided over the different categories; 22.6% of the participants had less than five years software development experience (N = 45), 25.1% six to ten years (N = 50), 20.6% 11 to 15 years (N = 41), and 31.2% more than 15 years (N = 62). Most respondents' core team role was developer (53.5%, N = 106), 11.1% of the respondents identified requirement analyst (N = 22) to be their core team role, an equal amount of testers participated in the study (11.1%, N = 22), 7.5% of the respondents was project manager (N = 15), 6.0% an architect (N = 12), and 11.1% of the participants identified another core team role (N = 22). Nearly half of the participants had been part of the team for over 18 months (49.2%, N = 98), 16.6% for 12 to 18 months (N = 33), 17.6% for six to 12 months (N = 35), and 16.6% for less than six months (N = 33).

Table 9 in Appendix D presents an overview of the teams and their characteristics; per team, average team size, main team assignment, type of application, application size in function points, and development method are given. Often, team members were not unanimous in their answer to a question. In these cases, we selected the answer that 50.0% or more of the team members selected. In some cases, this still left us with unanswered questions (no majority agreed to one answer) or multiple answers (the majority agreed on multiple answers). If this was the case, we selected the answer with the highest response rate. These cases are accentuated in table 9 (Appendix D).

Most teams were medium sized with an average of five to ten team members (48.3%, N = 14), a smaller percentage of the teams contained less than five members on average (31.0%, N = 7), and some of the teams were big, consisting of more than ten team members (20.7%, N = 5). For project duration, 34.5% of the projects (N = 10) had a short duration (less than six months), 27.6% (N = 8) a medium duration (six to twelve months), and 37.9% of the projects (N = 11) lasted more than 18 months. More than half of the projects concerned system new development (58.6%, N = 14), some system maintenance (17.2%, N = 5), system renovation (17.2%, N = 5) or system re-development (3,4%, N = 1). Most of the projects were business applications (75.9%, N = 22), a small percentage (6.9%, N = 2) was real-time applications, and five teams (17.2%) had other identifications for the type of application.

From the data in table 9 (Appendix D) it can be seen that a lot of team members did not know the meaning of a function point and/or the size of the application in function points. Only half of the teams (N = 14) agreed upon the size of the application expressed in function points. Another remarkable thing is that some team members indicated that the team was

Figure 3. *Overview of participant distribution*



using multiple development methods. In eight teams, more than half of the respondents indicated multiple development methods. This included combinations of agile and waterfall, incremental and agile, and two teams even indicated a combination of waterfall, incremental and agile. In these cases, we selected the development method with the highest response rate. Overall, most teams used an agile development method (55.2%, N = 16), 31.0% used the waterfall development method (N = 9), and 13.8% of the teams (N = 4) developed the application using incremental developing.

3.1.4 MEASURES

All factors being studied consider the team as unit of analysis. Hence, all respondents were asked to evaluate teamwork factors and performance of the team as a whole. The questionnaire was written in English, assuming all respondents possessed a sufficient command of English. Two professors from the information and social sciences domain examined the questionnaire in order to ensure validity of the content. Furthermore, a pre-test was conducted with a software development team of five members to test construct validity and the quality of the items. Based on the feedback given by the experts and the participants of the pilot study, minor changes were done to remove possible confusing or vague items before the final questionnaire was sent out.

We used existing, validated scales from the literature to measure the different factors. Table 3 shows an overview the number of items and the source of the TWQ and team performance measures. The complete questionnaires can be found in Appendix A and B.

Demographics. Demographic data were gathered, including respondent's demographic information and general information about the project. Demographic questions included questions concerning participants' age, sex, software development experience, time in team and team role. Questions about the software development project included questions about project and team size, planned duration, product type, size, and development method used.

Communication. Communication was measured by 5 items, adopted from Liang, Wu, Jian & Klein (2012), based on one of the teamwork quality facets of Hoegl and Gemuenden (2001). Items were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Questions included focused on the frequency of the communication, its spontaneity, team members' satisfaction of the timeliness of the information they received, the precision of it and the usefulness.

Table 2

Characteristics of sample population

Characteristic	Category	N	Percentage
Gender	Male	181	91.0
	Female	18	9.0
Age	<30	57	22.6
	31-40	67	34.2
	41-50	53	27.0
	>50	19	9.7
Educational background	IT	138	69.3
	Non-IT	49	24.6
	Other	12	6.0
Experience in software engineering	<5 years	45	22.6
	6-10 years	50	25.1
	11-15 years	41	20.6
	>15 years	62	31.2
Core team role	Requirement analyst	22	11.1
	Architect	12	6.0
	Developer	106	53.3
	Tester	22	11.1
	Project Manager	15	7.5
	Other	22	11.1
Time in team	<6 months	33	16.6
	6-12 months	35	17.6
	12-18 months	33	16.6
	>18 months	98	49.2
Average team size	<5 months	9	31.0
	5-10 months	14	48.3
	>10 months	6	20.7
Project duration	<5 months	10	34.5
	5-10 months	8	27.6
	>10 months	11	37.9
Main team assignment	System new development	17	58.6
	System renovation	5	17.2
	System re-development	1	3.4
	System maintenance	5	17.2
	Other	1	3.4
Type of application	Business application	22	75.9
	Real-time application	2	6.9
	Other	5	17.2
Development method	Waterfall	9	31.0
	Incremental	4	13.8
	RUP	0	0.0
	Agile	16	55.2

Table 3

Sources of teamwork quality measures

Teamwork Factors	Items	Adapted from
Communication	5	Lian, Wu, Jian & Klein (2012)
Coordination of Expertise	11	Faraj & Sproull (2000)
Cohesion	6	Chin, Salisbury, Pearson & Stollak (1999)
Trust	5	Jarvenpaa, Knoll & Leidner (2006)
Cooperation	6	Hoegl & Gemuenden (2001)
Value Diversity	6	Jehn (1994)
Project Performance	7	Jones & Harrison (1996)

Coordination of Expertise. Coordination of expertise was measured by 4 items for knowing expertise location, 3 items for recognizing the need of expertise, and 4 items for bringing expertise to good use (Faraj & Sproull, 2000). Items were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Cohesion. Cohesion was measured with the Cohesion Measurement Scale (CMS) of Chin, Salisburry, Pearson and Stollak (1999), adopted from the CMS of Bollen and Hoyle (1990). Participants were asked if they felt they belonged to the group, were happy to be part of the group, saw themselves as part of the group, considered the group to be one of the best anywhere, felt they were member of the group, and if they were content to be part of the group. The 6 items were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) to fit the setup of the survey.

Trust. The degree of trust within a team was measured by 5 items, adopted from Jarvenpaa and Leidner, 2006. Team members were asked if the people in their team were trustworthy, if they considered one another's feelings on the team, if team members were friendly, reliable and trustworthy. Measurements were done on a 5-point Likert scale (anchors from strongly disagree to strongly agree).

Mutual Support. Mutual support considered the degree to which, for example, team members supported each other, suggestions and contributions of other team members were respected and further developed, and the team was able to reach consensus regarding important issues. Coordination was measured with the 6 items of mutual support of Hoegl and Gemuenden (2001). Measures were done on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Value diversity. Value diversity was measured by 6 items, adopted from Jehn (1994). On a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), participants were asked if the values of all team members were similar, whether the team as a whole had similar work values, if the team as a whole had similar goals, if the team members had strongly held beliefs about what is important within the team, whether the team members had similar goals, and whether all member agreed on what was important to the team. High scores indicated low value diversity.

Team performance. Project performance was considered as the degree to which the project goals were achieved, the expected amount of work was completed, a high level of quality was delivered, the schedule was adhered, the operations were carried out efficiently and within time limits, and to which the budget was adhered (Jones & Harrison, 1996). These seven items were measured on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). These items, based on the scales developed by Henderson & Lee (1992), have been used in multiple studies to measure team performance (i.e. Wang, Chang, Jiang, & Klein, 2012; Liu, Chen, Chen & Sheu, 2011).

To control for internal consistency of the scales, we executed a Cronbach alpha test. All the scales had high reliabilities, all Cronbach's alpha ≥ .79. Three scales contained an item that would improve the reliability of the scale if it would be deleted. These concern the scale of cohesion and trust and that of team performance measured by stakeholder's evaluations. However, the increase in Cronbach's alpha would be negligible when deleting these items and since the scales were existing scales that have been validated in other research, we decided to maintain these questions. See table 4 for all Cronbach alpha scores.

To avoid common source bias and warrant content validity, the different variables were measured using multiple respondents. On the one hand, TWQ was measured using assessments from multiple team members. These individual assessments were aggregated to a measure of TWQ at the team level for each team. On the other hand, team performance was assessed both by team members and by stakeholders of the project. Stakeholders were assumed to give a more objective assessment of team performance.

3.2 DATA ANALYSIS

3.2.1 PRE-PROCESSING ANALYSES

Several pre-processing analyses were conducted. First, explorative analyses were conducted to describe the characteristics of the respondents. Furthermore, the Cronbach's alpha of all constructs was calculated. To rectify data aggregation from an individual level to a team level, we examined inter-rater agreement. We used the two-way random method, looking for the absolute agreement among raters. Overall, there was a strong inter-rater agreement within the teams. Given inter-rater reliability and, therefore, homogeneity of within-team ratings, data were aggregated at the team level by calculating the arithmetic mean. Test scores are included in table 4. Furthermore, Factor analyses were done to assess if all six factors belong to the same latent construct. Subsequently, we examined the correlations between the different variables.

3.2.2 STRUCTURAL EQUATION MODELING

Following Hoegl and Gemuenden (2001), the TWQ model was tested using structural equation modeling (SEM). The statistical software package AMOS 18 was used to employ this method. SEM allows the user to study the relationship among latent constructs that are indicated by multiple measures (Lei & Wu, 2007). Analyses were conducted using the unweighted-least-squares method (ULS), assuming non-normally distributed data. Following Hoegl and Gemuenden (2001), the six multiple-item TWQ scales were aggregated by calculating the arithmetic mean and treated as observed variables in the model, in order to reduce the number of free parameters. The error variance scales in the model were left unspecified.

Similar to the procedure described in Hoegl and Gemuenden (2001), the model was tested using the aggregated team level ratings (N = 29). However, SEM is a large sample technique wherefore sample size is preferably not less than 200 (Lei & Wu, 2007). Because of the small sample size at the team level, we also conducted a SEM using measures at the individual level. Missing data were replaced with the arithmetic mean of the team. To overcome the database design problem of the unequal amount of team members and shareholders, causing a lot of missing data, we used team member's measures of TWQ and performance at the individual level and the (aggregated) team level measures of performance of the stakeholders. Hence, the database included measures from the 199 team member respondents, supplemented with columns containing the (aggregated) measures of team performance as rated by the stakeholders of the corresponding team. Hence, SEM at the individual level was done using N = 199.

4. RESULTS

In this study, we examined how teamwork quality is related to team performance of software development project. Furthermore, we assessed how our model performs with respect to the original TWQ model of Hoegl and Gemuenden (2001). In this chapter, the results of the analyses will be presented.

4.1 TEAMWORK QUALITY AS A LATENT CONSTRUCT

To evaluate if all six TWQ factors relate to the same latent construct, factor analyses were conducted. A principal component analysis (PCA) with no rotation was conducted on the team level using aggregated team member responses. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = .82 ('great' according to Field, 2009), and all KMO adequacy for individual items were > .77, which is well above the acceptable limit of .5 (Field, 2009). Bartlett's test of sphericity χ^2 (15) = 159.16, p < .001, indicates that correlations between items were sufficiently large for PCA. An initial analysis was run to obtain eigenvalues for each component in the data. Only the first component had an eigenvalue over Kaiser's criterion of 1 and explained 79.81% of the variance. The scree plot was very clear and justified retaining only one component for further analyses. This latent construct represents TWQ.

Following Hoegl and Gemuenden (2001), we executed further factor analysis at the individual level (N = 199). Analyses at the individual level were done to ensure that the results at the team level (N = 29) were not the result of inflated correlations due to the

Table 4

Means, standard deviations, and reliabilities of the variables at the team level

	Mean	SD	Alpha[b]	ICC[c]
TWQ[a]				
Communication	3.78	0.62	.84	.79
Coo. of Exp.	3.78	0.53	.86	.82
Cohesion	4.04	0.64	.92	.88
Trust	4.07	0.52	.79	.76
Mutual Support	3.99	0.56	.88	.85
Value Diversity	3.48	0.67	.84	.86
Team Performance (Team Member Rating)				
Effectiveness	3.52	0.75	.82	.81
Efficiency	3.46	0.65	.79	.78
Team Performance (Stakeholder Rating)				
Effectiveness	3.70	0.81	.87	-
Efficiency	3.51	0.71	.76	-

[a] = team member ratings

[b] = cronbach's alpha coefficient

[c] = intra-class correlation coefficient

Table 5

Teamwork quality as a latent construct: Factor analysis, regression analysis, and reliability analysis at the team level

TWQ	Factor Loading	Std. Regr. Coefficients	*P*-Value
Communication	.88	.20	0.00
Coordination of Expertise	.89	.19	0.00
Cohesion	.92	.18	0.00
Trust	.88	.17	0.00
Mutual Support	.92	.16	0.00
Value Diversity	.88	.22	0.00
Eigenvalue	4.79		R^2 100%
Variance explained (Factor TWQ)	79.81%	Cronbach's alpha coefficient	0.95

Note. N = 29

aggregation of the data. Hoegl and Gemuenden (2001) followed two procedures to test the TWQ factor structure at the individual level. In our study, we only execute the first validation of reliability test procedure of Hoegl and Gemuenden (2001) to test the TWQ factor structure at the individual level. A random sample of 29 responses was used for factor analyses. This process was repeated 15 times. All factor analyses at the individual level support the findings at the team level; with all KMO measures being ≥ .77, all eigenvalues being greater than the Kaiser's criterion of 1 and total variance explained ranging from 58.78% to 83.12%. The results of these analyses are presented in table 10 (Appendix E).

Table 5 shows the factor loadings of the factor analysis at the team level and the standardized regression coefficients of a linear regression with the dependent variable being the (aggregated) TWQ construct. Table 6 presents the correlations between all TWQ factors and performance variables. All variables are significantly positively correlated to each other. As expected, all TWQ factors correlate highly to each other since they all refer to the same latent construct. Correlation plots of all TWQ factors with team performance as rated by stakeholders are shown in Appendix F.

4.2 DIFFERENT PERSPECTIVES ON TEAM PERFORMANCE

Both team members and stakeholders assessed team performance. It is interesting to see if team members and stakeholders interpret or experience team performance equally. Before comparing performance measures of team members and shareholders, we looked at the distribution of the variables (effectiveness and efficiency). The Sapiro-Wilk test shows that, apart from the effectiveness measure of stakeholders (*D* (28) = 0.90, *p* = .10), all team performance measures are normally distributed.

Comparisons of mean ratings of team performance do not result in significant differences. Because of the non-normal distribution effectiveness as rated by stakeholders

Figure 4. *Correlations between performance evaluations from different perspectives*

we executed a Mann-Whitney test to assess differences in effectiveness ratings between team members and stakeholders. The Mann-Whitney test reveals that stakeholders do not give significantly different ratings for effectiveness (M = 3.70, SE = 0.11) than team members (M = 3.52, SE = 0.05), U = 327.50, p = .21. A t test shows that stakeholders also do not give significant different ratings for efficiency (M = 3.51, SE = 0.10) than team members (M = 3.46, SE = 0.05), t (248) = -0.47, p = .92, r = .03.

Even though comparisons of mean ratings of effectiveness and efficiency as rated by team members and stakeholders do not result in significant differences, the results in figure 4 display correlations of varying magnitudes between these variables. While effectiveness ratings of team member and stakeholders correlate moderately (r > .30), there is a strong (r > .50) agreement between efficiency ratings of team members and stakeholders.

So, mean team member ratings of performance are not significant different to those of stakeholders. However, there is less coherence between team members' and stakeholders' evaluations of effectiveness (meeting project goals and completing the expected amount of

Table 6

Pearson correlations between the TWQ factors and team performance measures

	1	2	3	4	5	6	7	8	9	10
TWQ[a]										
(1) Communication	-									
(2) Coo. of Exp.	.79**	-								
(3) Cohesion	.78**	.77**	-							
(4) Trust	.62**	.78**	.81**	-						
(5) Mutual Support	.81**	.70**	.83**	.75**	-					
(6) Value Diversity	.70**	.75**	.73**	.75**	.81**	-				
Team Performance (Team Member Rating)										
(7) Effectiveness	.83**	.74**	63*	.60*	.65**	.62**	-			
(8) Efficiency	.71**	.63**	.75**	.65**	.78**	.74**	.79**	-		
Team Performance (Stakeholder Rating)										
(9) Effectiveness	.66**	.52**	.62**	.57**	.77**	.66**	.58**	.60**	-	
(10) Efficiency	.78**	.46*	.55**	.48**	.65**	.43*	.53**	.47*	.71**	-

Note. * p < .05, ** p < .001

[a] = team member ratings

work and quality) than their assessments of efficiency (adherence to schedule, efficiency and speed of task operations, and maintenance of the high morale during the project process).

4.3 TEAMWORK QUALITY AND TEAM PERFORMANCE

We investigated four structural equation models using the AMOS 18 statistical package. The analyses of first two models used the aggregated team level measures (N = 29). Model 1: TWQ (evaluated by team members) predicting team members' evaluations of team performance (N = 29). Model 2: TWQ (evaluated by team members) predicting stakeholders' evaluations of team performance (N = 29). The results of the analyses, including factor loading, standardized coefficients, variance explained (*R*-square), and goodness-of-fit measures (GFI, AGFI, RMR, Chi-Square, Degrees of Freedom, *p*-value), can be found in table 7. A graphical presentation of the model is presented in figure 5 (Appendix G). Circles represent latent variables and rectangles represent measured variables.The results for the models indicate strong overall model fit for Model 1 (GFI = .995, AGFI = .991, RMR = .008) and Model 2 (GFI = .996, AGFI = .993, RMR = .008). Values of GFI and AGFI lie well above the .90 threshold that indicates good model fit (Hooper, Coughlan & Mullen, 2008). Also RMR indicate good model fit, with values below .05 (Hooper, Coughlan & Mullen, 2008). The measures of the chi-square identify a good model fit too for Model 1 (χ^2 (19) = 0.061, *p* = 1.0)

Table 7

Results of the structural equation models at the team level

	Model 1. TWQ Predicting Team Members' Evaluations of Team Performance		Model 2. TWQ Predicting Stakeholders' Evaluations of Team Performance	
	Stand. Factor Loading	Stand. Coefficient/ *R*-Square	Stand. Factor Loading	Stand. Coefficient/ *R*-Square
Teamwork Quality (TWQ)				
Communication	.90		.89	
Coo. Of Exp.	.87		.81	
Trust	.82		.82	
Mutual Support	.90		.98	
Value Diversity	.85		.83	
Team Performance		0.90/0.81		0.78/0.60
Effectiveness	.91		.76	
Efficiency	.87		.93	
GFI (Goodness-of-Fit Index)		0.995		0.996
AGFI (Ajusted GFI)		0.991		0.993
RMR (Root Mean Square Residual)		0.008		0.008
Chi-Square		0.061		0.066
Degrees of Freedom		19		19
p-value		1.0		1.0

and Model 2 (χ^2 (19) = 0.066, p = 1.0). The results of the models support Hypothesis 1: higher TWQ corresponds to higher team performance. The predictive power of TWQ for team performance is different for team member and stakeholder ratings of performance. At the team level (N = 29), TWQ explains 81% of the variance in team performance as rated by team members and 60% as rated by stakeholders.

Because of the small sample size at the team level, we also conducted two structural equation model analyses at the individual level (N = 199). Model 1b: TWQ (evaluated by team members) predicting team members' evaluations of team performance (N = 199). Model 2b: TWQ (evaluated by team members) predicting stakeholders' evaluations of team performance (N = 199). Results of Model 1b and Model 2b are presented in table 11 (Appendix H).

The results show also a good overall model fit for Model 3 (GFI = .997, AGFI = .993, RMR = .001, χ^2 (19) = 1.417, p = .99) and Model 4 (GFI = .997, AGFI = .995, RMR = .001, χ^2 (19) = 0.873, p = 1.0). The difference in the magnitude of the relationship between TWQ and team performance as rated by the team members and stakeholders that was found at the team level, is confirmed at the individual level (N = 199). However, the predictive power of TWQ is found to be smaller; TWQ explains 66% of the variance in team performance as rated by team members and 40% as rated by stakeholders.

To conclude, TWQ is significantly related to team performance measures of both team members and stakeholders. TWQ has a higher explanatory power for performance as rated by team members than by stakeholders. These results are both found at the team level (N = 29) as the individual level (N = 199).

4.4 COMPARING THE ORIGINAL TWQ MODEL WITH THE NEW TWQ MODEL

When comparing the results of our analyses to those of Hoegl and Gemuenden (2001), we see that the explained variances of our TWQ models (Model 1 = 81%; Model 2 = 60%) are higher than those found by Hoegl and Gemuenden (2001) (table 8). Hoegl and Gemuenden

Table 8

Comparing explanatory powers of the original TWQ model with the new TWQ model

	Original TWQ Model	New TWQ Model	
	Team level	Team level	Individual level
TWQ predicting **team members**' evaluations of team performance	41%	81%	66%
TWQ predicting **stakeholders**' evaluations of team performance	11% / 7% (Team leaders / Managers)	61%	40%

(2001) found TWQ to explain 41% of the variance of team performance rated by team members, 11% as rated by team leaders, and 7% as rated by managers. Besides higher explained variance, we also find our model to fit the data better. The models of Hoegl and Gemuenden (2001) had significant Chi-squares. Despite the sensitivity to sample size, we found non-significant results for Chi-square on both team and individual level, indicating good model fit. These results support Hypothesis 2: The new Teamwork Quality model has a higher explanatory power than the original model of Hoegl and Gemuenden (2001). However, besides a better performing model, there are several alternative explanations possible for these results. These will be discussed in the next section.

5. DISCUSSION AND FUTURE RESEARCH

5.1 DISCUSSION

The purpose of this study was to examine the factors within software development teams that have significant influence on their performance to accomplish tasks. Even though a lot of time and money is being invested in software development, the success rate of software development projects is still disappointing (The Standish Group, 2009). Therefore it is important to know more about factors that influence team performance. The focus of our study was on the quality of interactions within software development teams. Based on the TWQ model (Hoegl & Gemuenden, 2001), general sociological research, and several arguments that questioned the selection of teamwork quality factors by Hoegl and Gemuenden (2001), a new TWQ model was developed and evaluated. The goal of the study was to verify if our assumption holds that a model that includes trust, value diversity, and coordination of expertise contributes more to explaining project success than the factors of Hoegl and Gemuenden (2001) alone.

The study aimed to answer the research questions about (1) how teamwork quality is related to the success of software development projects and (2) how the new TWQ model performs with respect to the original model of Hoegl and Gemuenden (2001). Two hypotheses regarding these two topics were tested. Three main findings were revealed:

1. There is a significant relationship between TWQ and the success of software development projects as measured by team performance (effectiveness and efficiency);
2. The magnitude of the relationship between TWQ and team performance differs with the perspective of the rater (team member versus stakeholder). TWQ explains 81% of the variance of team performance as rated by team members and 61% as rated by stakeholders;
3. The new TWQ model explains team performance better than the TWQ model of Hoegl and Gemuenden (2001). Compared to the original TWQ model, TWQ explains 40% more of the variance of team performance as rated by team members and more than 50% as rated by stakeholders.

Results support the conceptualization of TWQ as latent construct, as the six factors loaded high on one factor in both team- and individual-level factor analyses. This implies that the TWQ construct is a good measure of the collaborative nature of teams, focusing on the quality of the interactions within teams. The explained variance of the latent construct (TWQ) was almost eight percent higher than Hoegl and Gemuenden (2001) found for their model. This suggests that our adjustments have improved the model, implying that our model encompasses TWQ better than Hoegl and Gemuenden (2001).

Furthermore, the results of this empirical study show a significant relationship between TWQ and the success of software development projects. Based on data from 28 software development teams from the Netherlands and one from Ukraine, we found supporting results for the relationship between TWQ and performance that were found by Hoegl and Gemuenden (2001) and that were found in other earlier studies regarding the relationship between individual aspects of TWQ and performance (i.e. Pinto et al., 1993; Lian et al., 2011; Faraj & Sproull, 2000). TWQ was found to relate significantly to team performance measures (effectiveness and efficiency). Therefore, the TWQ model can be used as a tool to evaluate the quality of interactions within teams and get useful information for team management. Based on the TWQ model, managers can adjust their management activities to improve team collaboration.

The size of the relationships between each TWQ factor and the team performance measures were found to be equal. No significant differences were found between the correlations of the six TWQ factors with the measures of effectiveness and efficiency for both team members and stakeholders (see Table 6). However, communication, mutual support and coordination of expertise showed somewhat higher correlations with performance measures. This could suggest that communication and mutual support are of somewhat more importance for team performance than the other TWQ factors.

In general, TWQ explains 81% of the variance in team performance based on team member ratings and 60% of stakeholder ratings. The explanatory power of TWQ was found to be lower when the model was tested on the individual level (66% and 40% respectively). However, in most cases, TWQ explains more than half of the variance of team performance. Hoegl and Gemuenden (2001) also found a discrepancy between the explanatory power of TWQ on team performance between different types of raters (team members and stakeholders). Several possible reasons were given for these differences. One of the reasons could be that the raters have different properties or a different reference framework (Hauschildt, 1997). Team members have more knowledge about the details of the software product and the progress of the project, while stakeholders rely more on information given in controlling reports and information given in (progress) meetings. So team members have more ‘micro knowledge’, while stakeholders base their judgments on more ‘macro knowledge’ of the project. Hoegl and Gemuenden (2001) call this ‘macro vision’ a “bird’s-eye-view”. They suggest that managers may have been missing relevant details about performance of the team in terms of quality, schedule or budget. Furthermore, stakeholders’ ratings might be influenced by their perception of the overall performance of the larger development project or customer relationship to which a project team was contributing. Also, it is possible that stakeholders assess the performance of the team based on their overall impression of the expertise of the team leader or team members, instead of basing it merely on the actual performance of the team since they do not have better knowledge of the actual performance. Hoegl and Gemuenden (2001) note the importance of the discrepancy in performance measures issue. If, for example, financial bonuses or career opportunities are attributed to the level of performance, it is important that the involved parties reach consensus about the targeted and actual performance. If teams are to be managed and rewarded based on targeted and actual performance measures, more research should be done into this phenomenon.

However, there are several explanations for the difference in explanatory power between our TWQ model and that of Hoegl and Gemuenden (2001). First, our study was conducted 12 years after that of Hoegl and Gemuenden (2001). A lot of developments have taken place since. For example, after the "agile manifesto" was written in 2001 by Fowler and Highsmith, agile development methods have gained popularity and have been adopted by the industry with increasing rate every year (Hussain, Slany, & Holzinger, 2009). Such changes in the industry make it difficult to compare our sample to that of Hoegl and Gemuenden (2001). Second, there might be sample bias. In our study, we approached software development teams through our network and teams could decide whether to participate. Self-selection bias might have influenced our results. We found 29 teams that were willing to participate, while Hoegl and Gemuenden (2001) had about five times more participating teams (29 versus 145). However, Hoegl and Gemuenden (2001) only had twice as many respondents as we did (575 versus 252). Per team, Hoegl and Gemuenden (2001) had an average of 3.97 participants, including team members, team leaders and team managers. We had an average of 8.69 participants per team, including team members and stakeholders. So, when calculating the arithmetic mean for all the teams, Hoegl and Gemuenden's (2001) data were dependent on less data points and, therefore, more sensitive for extreme values. Third, we used a different measure for performance than Hoegl and Gemuenden (2001). Our measure of performance contained fewer items. Since the measure has been used and validated in multiple studies (i.e. Wang, Chang *et al.*, 2001; Liu *et al.*, 2011), we decided to use this measure to limit questionnaire size. However, it could have influenced the comparability of our data with that of Hoegl and Gemuenden (2001). Fourth, Hoegl and Gemudnen (2001) focus on innovative teams, we do not specifically focus on innovative software development teams. Also, we do not make a distinction between team members, leaders and managers. We made the separation between individuals that are closely related with the day-to-day practices of the team (team members) and individuals that do have interest in the success of the project but are not part of the day-to-day practices (stakeholders). Finally, the research method was different. Hoegl and Gemuenden (2001) conducted on site interviews. Respondents were asked to complete the questionnaire while the interviewer was present to clarify any questions if needed. We used an online questionnaire that participants filled out in their own time, at their own place, without knowing the researchers. Both methods have their advantages and disadvantages, and might influence the results in their own way. The important note is that it is harder to compare results when research methods are different. Fourth, mean values of all the variables are relatively high in Hoegl and Gemuenden's (2001) study. Since we have no accessibility to their data, we cannot know for sure, but it could be the case that they have a restriction of range effect, influencing the strength of their model.

To summarize, we cannot directly compare the results of our study one-to-one to those of Hoegl and Gemuenden (2001). However, the results suggest that a model including trust, value diversity, and coordination of expertise contributes more to explaining project success than the factors of Hoegl and Gemuenden (2001) alone. Further research seems essential to be able to make strong(er) statements about this. Nevertheless, the significant relationship between TWQ and performance indicates the importance of managing team collaboration in software development teams. This knowledge is useful for software managers to build and manage teams more constructively and enhance performance.

5.2 PRACTICAL IMPLICATIONS

Nowadays, organizations spend a lot of time and money on software development project. However, the success rate of these projects remains low. A lot of research is being done to investigate how the success rate of software development projects can be improved. Since software development primarily is a team effort and software quality has shown to be dependent on good teamwork, it is important to understand the factors or characteristics of software development teams that significantly influence team performance.

We found evidence that better teamwork creates better team performance. Results of our study show that, indeed, there is a strong and significant relationship between teamwork quality and team performance in software development. Since our study is cross-sectional rather than longitudinal, we cannot verify causality of this relationship. However, based on the magnitude of the relationship, software managers cannot deny that teamwork quality is an important factor in achieving good performance. The TWQ model offers managers a way to assess teamwork quality and be able to reflect on it. Software managers should recognize the importance of teamwork quality and focus their management activities on actively improving the six TWQ factors.

5.3 LIMITATIONS AND FUTURE RESEARCH

It should be noted that our study has a few limitations. First, the data for this research are from 28 Dutch and one Ukraine software development teams. The scope of the study, therefore, is somewhat limited. The study cannot easily be generalized to the bigger population. However, results at the individual level support the team level results, making it more likely that results can be generalized to the population. Nevertheless, generalization of the results only applies to the domain of software development. Software development teams need to work on complex tasks, in a constantly changing environment (Murray, 2000; Barry, Mukhopadhyay, & Slaughter, 2002). Good team collaboration is needed to be effective and work efficiently. When team tasks are less complex, teamwork quality might be a less important determinant for performance while other factors are. The TWQ model could be applicable in other domains, for example sports. However, minor changes should possibly be made to the model to make it more applicable for other domains. Further research should clarify this. This study aimed at the domain of software development teams and we encourage further empirical research at larger scales to justify generalizability of our results.

Second, being a cross-sectional study, results cannot provide definite information about the causality of the relationship between TWQ and performance. A longitudinal study could expand our knowledge about the causality of this relationship and about the development of team collaboration and the perception of performance over time.

Third, there is no objective assessment of team performance. By using performance assessments from different perspectives we tried to make it more objective, however, future research could use a more objective measure of performance. Having no objective assessment of TWQ, this may be the reason why the explained variance is so high.

However, even though TWQ explains a big portion of the variance in team performance, there is still a part of the variance left unexplained. We focused on the quality of interactions within teams, leaving other aspects such as development method, complexity, organizational context, and leadership out of scope. Empirical research into the potential moderating effect of such factors is desired. Due to the scope constrain, we did not incorporate these factors in our analyses. However, we are planning to take these factors into account in future reports. Furthermore, in our study, the results of measures of development method and project size raise multiple questions. In multiple teams we observed team members having multiple and/or different interpretations of development method and project size. Some teams simultaneously specified agile and waterfall development methodology, while, in theory, the one excludes the other. Waterfall is a linear and sequential design process, whereas agile is based on iterative and incremental development. Our findings, therefore, indicate that it could be the case that the respondents do not know the theory behind their practices. Maybe they did not understand the question or they do not grasp the mutual exclusion. Or possibly they are in a process moving from waterfall to agile development methods. Also, a lot of respondents did not know the size of the application in terms of function points or did not know the definition of a function point at all. Perhaps is the number of function points not a common measure for project size. However, most participants could not express project size in another measure either. We encourage research being done about the consciousness of software development team members about their practices. If software development team members do not know the theory behind their practices, where do they base their practices on?

Fifth, our study copied they analytical method from Hoegl and Gemuenden (2001), which is a good way to create a second order construct as TWQ, but is less suitable to assess of the three new added factors actually are better in explaining performance than the three original factors. If we want to assess if the three new added factors actually are better in explaining performance than the original three factors, the study should have either also measured the factors of the original TWQ model, or regress all factors on performance to see which are significant or not. We are planning to do the last thing and report in the results in future reports. However, for this thesis this was out of scope.

Finally, as this thesis provides empirical evidence for the influence of TWQ on software team performance, further research should investigate the antecedents of TWQ. What can software managers do to enhance high team collaboration?

7. CONCLUSION

Research has shown that software quality, to a large extent, is dependent on good teamwork (Hoegl & Gemuenden, 2001; Liang *et al.*, 2012; Henderson & Lees, 1992). Since the success rate of software development projects is low (The Standish Group, 2009), it is important to understand the factors of software development teams that have a significant influence on performance. Based on the TWQ model (Hoegl and Gemuenden, 2001), general sociological research, and several arguments that questioned the selection of teamwork quality factors by Hoegl and Gemuenden (2001), a new TWQ model was developed and evaluated including the following six TWQ factors: *communication*, *coordination of expertise, cohesion, trust, mutual support,* and *value diversity*. The goal of the research was to verify if our assumption holds that a model that includes trust, value diversity, and coordination of expertise contributes more to explaining project success than the factors of Hoegl and Gemuenden (2001) alone. Based on data from 28 software development teams from the Netherlands and one from Ukraine, the relationship between TWQ and team performance was investigated to give answer to the question which factors predict software development success. Furthermore, we tried to answer the question whether our model is a better predicts team performance better than the model of Hoegl and Gemuenden (2001).

The main contribution of this thesis is that we found significantly stronger support for the notion that better teamwork creates better software than previous research has found. The results of our study support three main findings: (1) There is a significant relationship between TWQ and the success of software development projects as measured by team performance (effectiveness and efficiency); (2) The magnitude of the relationship between TWQ and team performance differs with the perspective of the rater (team member versus stakeholder). TWQ explains 81% of the variance of team performance as rated by team members and 61% as rated by stakeholders; (3) The new TWQ explains team performance better than the TWQ model of Hoegl and Gemuenden (2001). Compared to the original TWQ model, TWQ explains 40% more of the variance of team performance as rated by team members and more than 50% more as rated by stakeholders.

However, critical notes were given for the generalizability of our results and the comparability of our model to that of Hoegl and Gemuenden's (2001). Future research on a larger scale should be performed to verify our results. Furthermore, we encourage longitudinal research on the relationship between TWQ and performance to gain more knowledge about the causality of this relationship and about the development of team collaboration and the perception of performance over time. Nevertheless, our results confirm the importance of TWQ in software development teams, being a significant predictor of team performance.

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APPENDICES

APPENDIX A: TEAM MEMBER QUESTIONNAIRE

Page 1.
Thank you for participation in our research about teamwork and team performance in software development teams. This research focuses on the 'soft' factors that play a role in software development teams. With your participation, you play an important role in the scientific research about the dynamics of software development teams.

As researchers, we adhere to the law of personal protection and the "Conduct for the use of personal information in scientific research" of Tilburg University. The questionnaire is completely anonymous and confidential. Filling out the questionnaire will take you about 10-15 minutes.

First, several general questions will be asked. Then, several propositions will be presented. You will be asked to identify to which extent you agree with the propositions. There are five possibilities:

1. I **strongly disagree** with the proposition
2. I **disagree** with the proposition
3. I **do not agree neither disagree** with the proposition
4. I **agree** with the proposition
5. I **strongly agree** with the proposition

Space for possible comments or remarks is given at the end of the questionnaire.

Good luck!

Kind regards,

Emily Weimar

Page 2.
1.
Company name

2.
Team name

3.
Gender:
O Male
O Female

4.
Age

5.
Educational Background
O IT (e.g. computer science, business informatics, etc.)
O Non-IT (e.g. psychology, chemistry, economics, etc.)
O Other, namely: _______________

6.
Experience in Software Development
O Less than 5 years
O 6-10 years
O 11-15 years
O More than 16 years
O Not applicable

7.
Core Team role
O Requirement analyst
O Architect
O Developer
O Tester
O Project Manager
O Other, namely: _______________

8.
Team size
O Less than 5
O 5-10
O More than 10

9.
Planned Project Duration
O Less than 6 months
O 6-12 months
O 12-18 months
O More than 18 months

10.
Time in Team
O Less than 6 months
O 7-12 months
O 13-18 years
O More than 18 months

11.
Main team assignment
O System new development
O System renovation (enhancement)
O System re-development
O System maintenance
O Other, namely: _______________

12.
Type of application that best describes the system
O Business application
O Mathematically intensive application
O Real-time application
O Infrastructure software (e.g., DBMS, software utilities)
O Other: _______________

13.
Size of the application in Function Points
O Less than 10 function points
O 10-100 function points
O 100-1.000 function points
O 1.000-10.000 function points
O More than 10.000 function points
O Other measure: _______________

14.
Development method(s) used in developing the system
O Waterfall
O Incremental Development
O Rapid Application Development
O Rational Unified Process (RUP)
O Agile development
O Other: _______________

Page 3.
15. ***Communication***
Give your opinion about the following propositions:

	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
There is frequent communication within the team	O	O	O	O	O
Team members communicate often in spontaneous meeting, phone conversations, etc.	O	O	O	O	O
Team members are happy with the timeliness in which they received information from other team members	O	O	O	O	O
Team members are happy with the precision in which they received information from other team members	O	O	O	O	O
Team members are happy with the usefulness in which they received information from other team members	O	O	O	O	O

16. ***Mutual Support***

Give your opinion about the following propositions:

	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
The team members help and supported each other as best as they can	O	O	O	O	O
If conflicts come up, they are easily and quickly resolved	O	O	O	O	O
Discussions and controversies are conducted constructively	O	O	O	O	O
Suggestions and contributions of team members are respected	O	O	O	O	O
Suggestions and contributions of team members are discussed and further developed	O	O	O	O	O
Our team is able to reach consensus regarding important issues	O	O	O	O	O

17. ***Cohesion***

Give your opinion about the following propositions:

	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
I feel that I belong to this team	O	O	O	O	O
I am happy to be part of this team	O	O	O	O	O
I see myself as part of this team	O	O	O	O	O
This team is one of the best anywhere	O	O	O	O	O
I feel that I am member of this team	O	O	O	O	O
I am content to be part of this team	O	O	O	O	O

18. ***Trust***

Give your opinion about the following propositions:

	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
Overall, the people in my team are very trustworthy	O	O	O	O	O
We are usually considerate of one another’s feelings on this team	O	O	O	O	O
The people in my team are friendly	O	O	O	O	O
I can rely on those with whom I worked in my team	O	O	O	O	O
There is a noticeable lack of confidence among those I worked with	O	O	O	O	O

Page 4.

19. ***Value Diversity***

Give your opinion about the following propositions:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The values of all team members are similar	O	O	O	O	O
The team as a whole has similar work values	O	O	O	O	O
The team as a whole has similar goals	O	O	O	O	O
Team members have strongly held beliefs about what is important within the team	O	O	O	O	O
Team members have similar goals	O	O	O	O	O
All members agree on what is important to the team	O	O	O	O	O

20. ***Coordination of Expertise***

Give your opinion about the following propositions:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
The team has a good “map” of each others' talents and skills	O	O	O	O	O
Team members are assigned to tasks corresponding to their task-relevant knowledge and skill	O	O	O	O	O
Team members know what task-related skills and knowledge they each possess	O	O	O	O	O
Team members know who on the team has specialized skills and knowledge that is relevant to their work	O	O	O	O	O
Some team members lack certain specialized knowledge that is necessary to do their task (R)	O	O	O	O	O
Some team members do not have the necessary knowledge and skill to perform well - regardless of how hard they try (R)	O	O	O	O	O
Some people on our team do not have enough knowledge and skill to do their part of the team task (R)	O	O	O	O	O
People in our team share their special knowledge and expertise with one another	O	O	O	O	O
If someone in our team has some special knowledge about how to perform the team task, he or she is not likely to tell the other member about is (R)	O	O	O	O	O
There is virtually no exchange of information, knowledge, or sharing of skills among members (R)	O	O	O	O	O
More knowledgeable team members freely provide other members with hard-to-find knowledge or specialized skills	O	O	O	O	O

Page 5.

20. ***Team Performance***

Give your opinion about the following propositions:

	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**
Project goals are met	O	O	O	O	O
The expected amount (scope) of work is completed	O	O	O	O	O
The expected quality of work is achieved	O	O	O	O	O
The schedule is adhered to	O	O	O	O	O
Task operations are carried out efficiently	O	O	O	O	O
Task operations are carried out as fast as possible	O	O	O	O	O
The members maintain the high morale during the project process	O	O	O	O	O

21.

If you have any comments or remarks about factors in your team that influence your team performance, please write them down below.

Submit

Thank you for your participation!

Kind regards,

Emily Weimar

APPENDIX B: SHAREHOLDER QUESTIONNAIRE

Page 1.

Thank you for participation in our research about teamwork and team performance in software development teams. This research focuses on the ‘soft’ factors that play a role in software development teams. With your participation, you play an important role in the scientific research about the dynamics of software development teams.

As researchers, we adhere to the law of personal protection and the “Conduct for the use of personal information in scientific research” of Tilburg University. The questionnaire is completely anonymous and confidential. Filling out the questionnaire will take you about 5 **minutes**.

First, several general questions will be asked. Then, several propositions will be presented. You will be asked to identify to which extent you agree with the propositions. There are five possibilities:

1. I **strongly disagree** with the proposition
2. I **disagree** with the proposition
3. I **do not agree neither disagree** with the proposition
4. I **agree** with the proposition
5. I **strongly agree** with the proposition

Space for possible comments or remarks is given at the end of the questionnaire.

Good luck!

Kind regards,

Emily Weimar

Page 2.

1.
Company name

2.
Team name

3.

What is your role in relation to the project?

4. ***Team Performance***

Give your opinion about the following propositions:

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
Project goals are met	O	O	O	O	O
The expected amount (scope) of work is completed	O	O	O	O	O
The expected quality of work is achieved	O	O	O	O	O
The schedule is adhered to	O	O	O	O	O
Task operations are carried out efficiently	O	O	O	O	O
Task operations are carried out as fast as possible	O	O	O	O	O
The members maintain the high morale during the project process	O	O	O	O	O

5.

Which aspects in the development team require further improvement?

6.

Please indicate if you have additional remarks concerning the performance of the software development team or other remarks you want to share.

Submit

Thank you for your participation!

Kind regards,

Emily Weimar

APPENDIX C: ACCOMPANYING EMAIL OF QUESTIONNAIRES

Dear participant,

Thank you for your participation in our study about team performance in software development teams. You can find a link to the digital questionnaire at the end of this email. To be able to access the questionnaire, you are asked to fill out a password. The **password = teamwork**.

The questionnaire will take you about **10-15 minutes***. Please give attention to the following instructions:

- Find a **quiet spot** to complete the questionnaire
- **Take your time** to complete the questionnaire
- Complete the questionnaire in **one go**
- Make sure you are **not disturbed**
- Be **honest** while filling out the questionnaire

All results are **anonymous** and treated **confidentially**. Further instructions will be given at the start of the questionnaire. However, the questionnaire should be self-explaining.

Link to questionnaire:
http://www.thesistools.com/web/?id=XXX&code=XXX

Thank you again for your participation and good luck.

Emily Weimar | Research Intern
+31 (0)6 523 362 19| e.weimar@sig.eu
Software Improvement Group | www.sig.eu

* In the shareholder email this is 5 minutes

APPENDIX D: OVERVIEW OF TEAM CHARACTERISTICS

Table 9

Overview of all team characteristics

Org.	Team	n	Team size	Project duration	Main assignment	Type of application	Application size	Development method
1	1	3	5-10	6-12	Renovation	**Other***	10-100	Incremental / **Agile****
2	2	6	5-10	> 18	Maintenance	Business	-	Agile
3	3	16	> 10	< 6	Maintenance	Business	-	Waterfall
	4	4	> 10	6-12	Maintenance	Real-time	-	**Waterfall**** / RUP
	5	18	> 10	< 6	**New development***	Business	-	Waterfall
4	6	11	> 10	> 18	New development	Business	1.000-10.000	Agile
5	7	4	**5-10**	< 6	New development	Business	100-1.000	Agile
6	8	12	5-10	< 6	Maintenance	Business	-	**Waterfall**** / Agile
7	9	3	< 5	< 6	New development	Other	-	**Incremental**** / Agile
8	10	5	5-10	> 18	New development	Business	-	Agile
9	11	8	5-10	> 18	New development	Business	100-1.000	RUP / **Agile****
	12	4	< 5	> 18	**Renovation**** / Maintenance	Business	1.000-10.000	Incremental
	13	6	5-10	6-12	New development	Business	100-1.000	Agile
	14	25	> 10	> 18	**Renovation***	Business	1.000-10.000	Agile
10	15	11	5-10	6-12	New development	Business	> 10.000	Agile
11	16	4	< 5	< 6	New development	Business	> 10.000	Incremental
12	17	3	< 5	> 18	New development	Business	> 10.000	**Incremental**** / Agile
13	18	5	< 5	6-12	New development	Real-time	1.000-10.000	Waterfall
14	19	9	5-10	> 18	**New development**** / Maintenance	Business	-	Agile
	20	6	5-10	**6-12**	New development	Business	> 10.000	Agile
15	21	4	5-10	> 18	System renovation	Business	100-1.000	Waterfall
	22	6	5-10	> 18	Maintenance	Business	-	**Waterfall**** / Incremental / Agile
	23	2	**5-10**	**6-12**	**Other***	**Other***	-	**Waterfall***
16	24	3	< 5	< 6	New development	Business	-	Waterfall / Incremental / **Agile****
17	25	5	5-10	6-12	New development	Business	-	Agile
	26	2	**< 5**	**< 6**	Re-development	**Business***	-	Agile
	27	4	> 10	6-12	New development	Business	-	Waterfall
18	28	3	< 5	< 6	New development	Other	100-1.000	Agile
	29	7	5-10	> 18	**Renovation***	**Other***	-	Agile

* Answer with highest response rate when no majority (> 50%) selected the same answer.

** Multiple answers were selected by the majority (> 50%), this is the answer with the highest response rate.

APPENDIX E: TEAMWORK QUALITY AS A LATENT CONSTRUCT

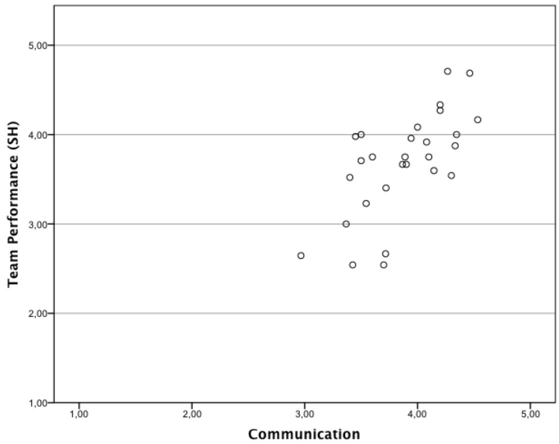
Table 10

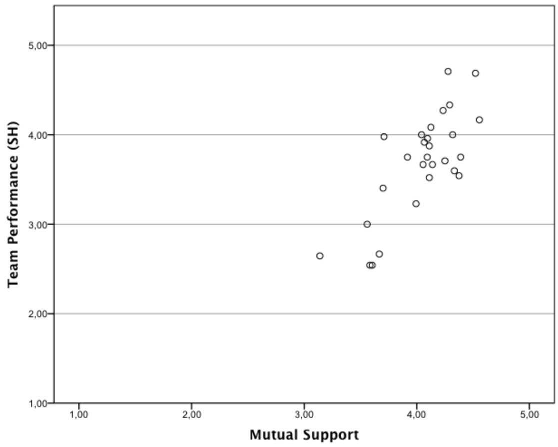
Teamwork quality as a latent construct: Factor analysis at the individual level

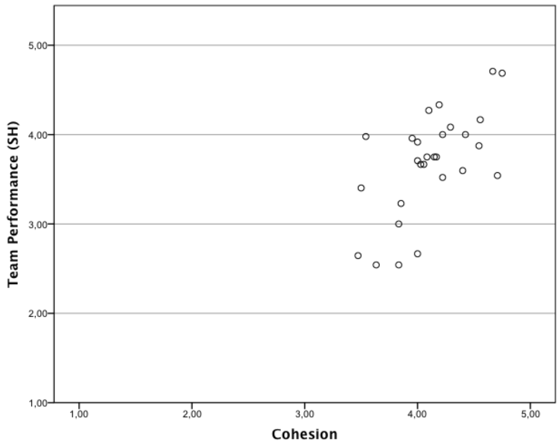
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
KMO	.77	.92	.82	.87	.84	.78	.88	.81	.82	.82	.88	.84	.88	.82	.79
TWQ															
Communication	.82	.84	.75	.91	.69	.68	.84	.89	.75	.72	.72	.70	.83	.88	.87
Coor. of Exp.	.85	.93	.78	.85	.82	.72	.91	.68	.93	.85	.89	.86	.78	.85	.80
Cohesion	.86	.94	.75	.81	.74	.79	.83	.81	.87	.73	.85	.81	.78	.84	.91
Trust	.76	.91	.82	.82	.84	.78	.81	.74	.81	.79	.84	.83	.83	.84	.87
Cooperation	.89	.93	.87	.92	.92	.85	.82	.89	.90	.86	.93	.95	.89	.90	.86
Value Diversity	.88	.93	.92	.83	.84	.76	.86	.80	.89	.86	.90	.82	.82	.84	.87
Eigenvalue	4.28	4.99	4.01	4.40	3.96	3.53	4.31	3.89	4.43	3.87	4.40	4.15	4.05	4.40	4.47
Variance explained	71.38	83.12	66.84	73.34	65.95	58.78	71.79	64.89	73.90	64.57	73.30	69.10	67.55	73.38	74.77

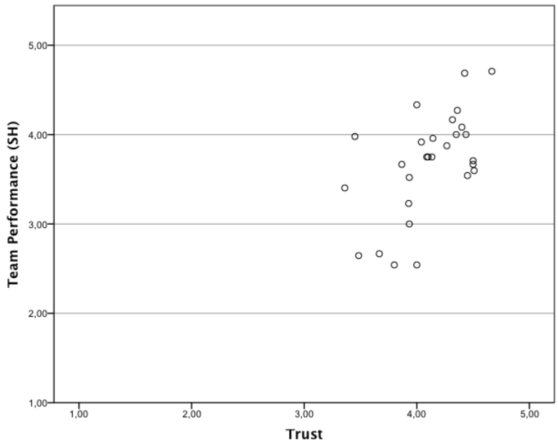
APPENDIX F: CORRELATION PLOTS BETWEEN TWQ FACTORS AND TEAM PERFORMANCE

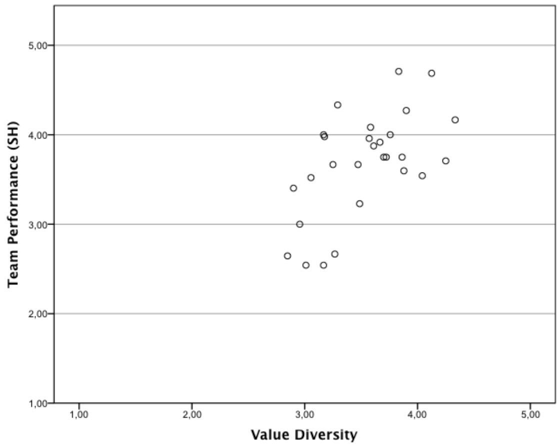
F.1 CORRELATION PLOTS BETWEEN TWQ AND TEAM PERFORMANCE AT TEAM LEVEL

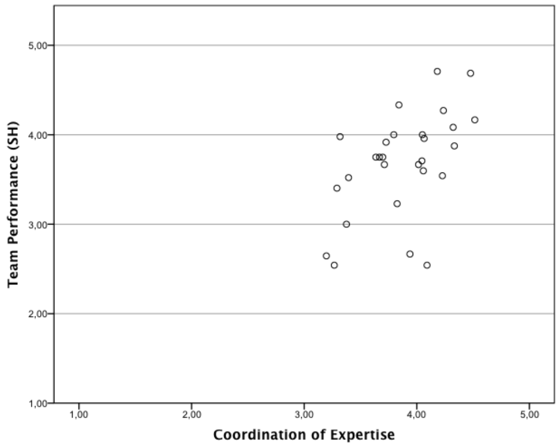




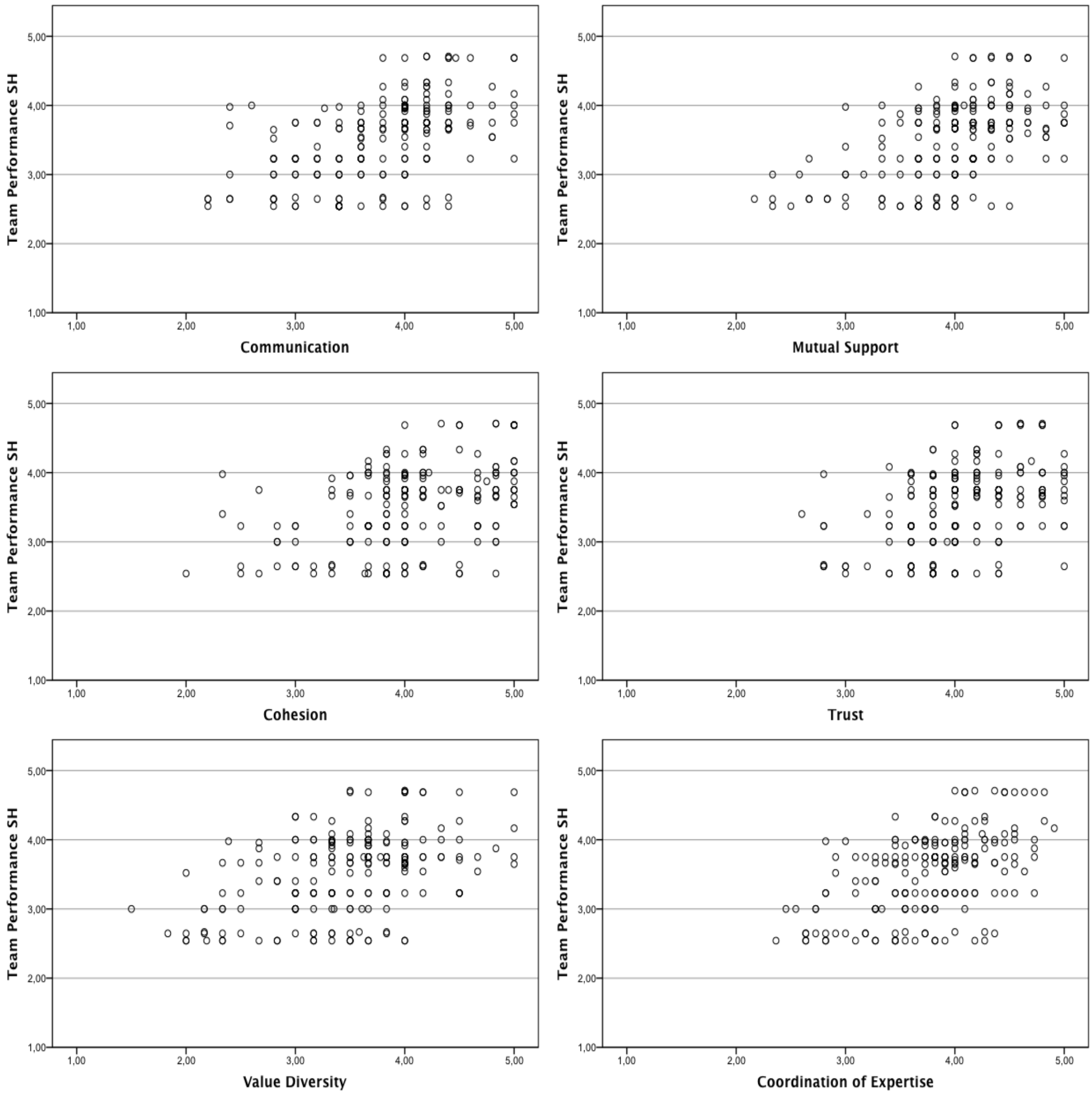






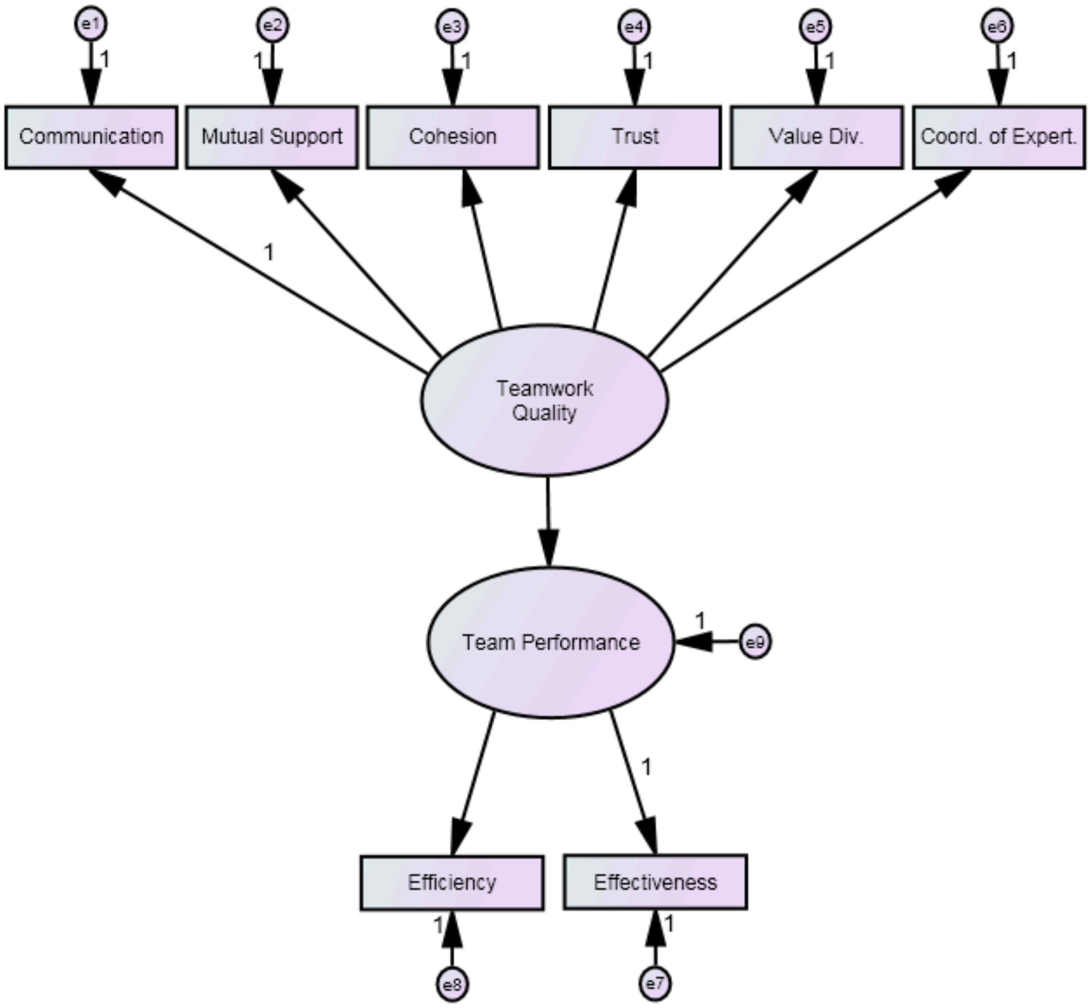


F.2 CORRELATION PLOTS BETWEEN TWQ AND TEAM PERFORMANCE AT INDIVIDUAL LEVEL



APPENDIX G: GRAPHICAL REPRESENTATION OF THE TWQ MODEL

Figure 5. *Graphical representation of the TWQ model in AMOS*



APPENDIX H: STRUCTURAL EQUATION MODELING AT THE INDIVIDUAL LEVEL

Table 11

Results of the structural equation models at the individual level

	Model 1b. TWQ Predicting Team Members' Evaluations of Team Performance		Model 2b. TWQ Predicting Stakeholders' Evaluations of Team Performance	
	Stand. Factor Loading	Stand. Coefficient/ *R*-Square	Stand. Factor Loading	Stand. Coefficient/ *R*-Square
Teamwork Quality (TWQ)				
Communication	.80		.79	
Coo. Of Exp.	.82		.82	
Trust	.74		.76	
Mutual Support	.84		.87	
Value Diversity	.84		.81	
Team Performance		0.81/0.66		0.64/0.40
Effectiveness	.79		.92	
Efficiency	.90		.83	
GFI (Goodness-of-Fit Index)		0.997		0.997
AGFI (Ajusted GFI)		0.993		0.995
RMR (Root Mean Square Residual)		0.014		0.011
Chi-Square		1.417		0.873
Degrees of Freedom		19		19
P-Value		.99		1.0

Note. N = 199