Measuring communication complexity in projects

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Abstract
Recent researches shows that software projects fail to meet their requirements in terms of time delay, cost overrun and quality restrictions. It is widely accepted that among the main reasons for these failures is the increased complexity of modern software projects arising from their special characteristics in comparison with projects from other domains. Software projects are affected of rapidly technological changes, are immaterial and supple. Current studies measure software project complexity by measuring either the software project product based on its attributes such as size, quality, reliability or the characteristics of software project process using attributes such as performance, stability, improvement. According to our approach these methods are not adequate as they do not focus in the software project development management process. This study, propose the managing of complexity in software projects by applying project management techniques, based on PMBOK, in software project development process and focuses on communication management. Communication management is among the most important knowledge areas in project management. Communication complexity sources that identified are project stakeholders' properties, project environment, project communication structure, communication properties, physical and psychological barriers. A discussion exploring how these affects project communication performance is taken place. Finally for each complexity source a set of quantitative metrics and appropriate evaluation method are proposed to measure communication complexity.

Keywords: communication, communication management, complexity, metrics, project management

JEL classification: M15, M16, O22

Introduction

This research aims in defining the concept of complexity in software projects and as well a model to measure it.

Project Management (PM) is widely accepted today as an important management tool in business development and business success (PIPC, 2005). As consequence, a great progress has been achieved in PM

techniques and in the way these techniques have been applied to projects. There are many PM frameworks that have been developed over the past few decades. Among of the most known is the "Project Management Body Of Knowledge" (PMBOK) from Project Management Institute (PMI, 2004), the "IPMA Competence Baseline" (ICB) from International Project Management Association (IPMA, 2006) and the "Projects IN a Controlled Environment" (PRINCE2) from the formerly named Central Computer and Telecommunications Agency (CCTA).

Even though PM has received a lot of attention from industry and academia, a great number of projects still fail to meet their requirements in terms of time delay, cost overrun and quality restrictions (Holmes, 2001; KPMG, 2003, Flyvbjerg et al., 2003; Morris and Hough, 1987). Most of these failures have been attributed to the complexity of the projects. Project complexity lead to project failure because either complexity is very high (Williams, 2002, 2005), either project complexity has been underestimated (Neleman, 2006). Many studies have been undertaken the last years in order to understand, define and determine the concept of project complexity (Bosch-Rekveldt and Mooi,2008; Dombkins and Dombkins, 2008; Geraldi and Adlbrecht,2007; Hass, 2007; Maylor et al., 2008; Vidal and Marle, 2008;Williams, 2002).

Projects as such are complex systems, which involve a great number of factors, where in many cases, are beyond the project manager's control. Software projects are among the most complex ones. Many studies on various types of software project have proven that their outcomes are far from the complete fulfillment of the initial requirements (Standish Group, 1995, 2009; Charette, 2005). Although the study of complexity in software projects is not something new, most studies measure complexity either by measuring the software project product based on its attributes such as size, quality, reliability or the characteristics of software project process using attributes such as performance, stability, improvement (Laird and Bennan, 2006; Florac et al, 1997; Fitsilis et al, 2010). These approaches seem not to be adequate to measure complexity because "in complex systems the whole is more than the sum of parts" and "given the properties of the parts and the laws of interaction, it is not trivial to infer the properties of the whole" (Simon, 1962). For example, strict or complicated time, cost, quality, communication constraints either separately or in combination can increase project complexity regardless of the complexity of the final product. So it is necessary to take into consideration and other factors in measuring project complexity. The aforementioned approaches do not take into consideration aspects such as communication management, time management, cost management, scope management and therefore the need to develop a specific model for software project management (SPM) becomes apparent. Considering the above, it is obvious that many failure factors would have been restrained, if not eliminated, if project management techniques were applied in software development process in order to manage complexity. The relationship between project complexity and PM has already started to be investigated (Cooke-Davies et al., 2007).

In this paper, we present and analyze measures that handle communication project complexity. The remaining of the paper is structured as such: chapter 2 presents the literature review on software project complexity, section 3 presents the dimensions and measures that focus on communication project complexity. In section 4

the presented project communication measures are analysed and compared, while in the last section we present conclusions and future work.

Literature review

The theoretical basis of this project is threefold: It based on Project Management theories, Complexity theories and Software Engineering theories.

Project management theories.

The concept of PM has emerged a few decades ago in the 50's. It was then that the two basic mathematical models, Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM) were that developed (Meredith and Mantel, 2008). The development of large construction and software projects created the demand for advances in the theoretical background, the methodologies and techniques for managing large projects. Nowadays project management is widely accepted as a very important factor in project success and therefore there are many organizations that try to promote the development of project management (PIPC, 2005). Project Management Institute (PMI) has proposed PMBOK, which has globally accepted as one of the main standard for PM, both from companies and International Organizations (IEEE and ANSI). PMBOK defines nine knowledge areas (PMI Institute, 2004) which are Project Integration Management, Project Scope Management, Project Time Management, Project Cost Management, Project Quality Management, Project Human Resource Management, Project Communication Management, Project Risk Management and Project Procurement Management. International Project Management Association (IPMA) proposed the IPMA Competence Baseline (ICB) which describes in detail the competences that are required for project management. These competencies are classified in three main categories (IPMA, 2006), which are the technical competencies, the behavioral competences and contextual competences. The main difference between those two frameworks is that PM according to ICB approach, is based on skills and competences and it is strongly influenced from the project environment, whereas PMBOK approaches PM in an empirical and process based point of view.(PMI Institute, 2004; IPMA, 2006).

Complexity theories.

Complexity is part of our environment and appears in different domains of our life. Many scientific fields have dealt with complex systems and have attempted to define the term complexity from their own point of view. This implies that there is a different definition of complexity in computational theory, in information theory, in business, in software engineering etc. Obviously it is essential to define and understand the complexity determinants in various science domains. Davidson (2002) states that "Project Management has operated in a management environment of chaos and complexity for decades". Consequently the need of first understanding and secondly managing the complexity is significant in order to achieve project success. "Complexity refers to the study of complex systems, of which there is no uniformly accepted definition because, well, they are complex" stated by Parwani (2002). According to Whitty and Maylor (2009), often project managers have a difficulty to determine the term complex; for example, they cannot distinguish the difference between complex and complicated. Some synonyms for term complex are difficult,

complicated, involved, tangled, knotty etc (Whitty and Maylor, 2009). However a definition of project complexity should at least contain interaction, structural and dynamic elements (Whiity and Malor, 2009). Baccarini (1996) proposed the complexity to be operationalized in terms of differentiation and interdependency as follows:

- **Organizational Complexity by differentiation.** It has two dimensions. The first one refers to organizational structure and the second one to organizational units and to the division of task.
- **Organizational complexity by interdependency.** It refers to "the degree of operational interdependences and interaction between the project organizational elements" (Baccarini, 1996).
- **Technological complexity by differentiations.** It refers to variety of tasks such as the number of inputs and outputs, the number of specialists, number of actions etc.
- **Technological complexity by interdependency** which refers to interdependency between tasks, teams different technologies etc.
- Extending the work of Baccarinni, Williams (1999) added the dimensions of uncertainty in projects and the multi-objectivity and multiplicity of stakeholders. On the same issue Geraldi and Adlbrecht (2006) and Geraldi (2008) defined three types of complexity.

- **Complexity of Faith (CoFaith**), which refers to the complexity involved in creating something unique or solving new problems. This type of complexity occurs due to uncertainty.
- **Complexity of Fact (CoFact)**, which refers to the complexity in dealing with a very large amount of interdependent information where there is no time to fully process and understand them but a decision must be taken immediately.
- **Complexity of Interaction (CoInt)**, which refers to characteristics that intensify both types of complexity mentioned above and usually presented in interfaces between systems or locations of complexity such as ambiguity, neutrality etc.

Considering complexity, software projects are quite similar with projects in other areas concerning the factors that influence it, for example the tools, the processes, the restrictions to name a few (Fitsilis and Stamelos, 2007). Bechtold (1999), Hudges (1999), and Kiountouzis (1999) state that software projects differ in the facts that is immaterial, complicated, supple and technology dependent. Furthermore Xia and Lee (2004) state that information systems projects "are inherently complex because they deal not only with technological issues but with organizational factors largely beyond the project team's control" (Xia and Lee, 2004). Summarizing we should study complexity, that stems from conceptual complexity, structural complexity, team complexity etc (Laird and Brennan, 2006; Camci and Kotnour,2006; Antoniadis, 2009)

As a consequence there is no surprise that the most common result in a software project is "failure". By the term "failure" we mean the failure to deliver the required quality of functionality within the given time and cost. (Flyvbjerg et al., 2003; Hall, 1981; Morris and Hough, 1987; Thamhain and Wilemon, 1986). So in order to reduce the failure we have to measure and control complexity. Whitty and Maylor (2009) propose the use of complexity as a metric, to measure complex in a system. So complexity should be deal as a variable that we should

to measure, if we want to be helpful in PM. In this case we can use complexity as thermometer by developing – "complexometer" (Geraldi, 2008) and in the question "How complex is this project?" to reply "Its complexity is…..." (Whitty and Maylor, 2009).

Software engineering theories

The IEEE Computer Society's Software Engineering Body of Knowledge defines "software engineering" (SWEBOK, 2004) as the application of a systematic, disciplined, quantifiable approach to the development, operation, and maintenance of software, and the study of these approaches. The first years of computing, software was closely related to hardware. As computer hardware and software evolved different types of software introduced such as operating systems, application software, programming languages etc. Later the notion of Software Development Life Cycle (SDLC), the Open Source software and distributed software development appeared. Thus the software developers start to deal with increasing complexity of software systems. The complexity concerns both the software product and the software development process. As a response to this, pressing and demanding need to handle the infinitive complexity of process oriented software development a set of empirical software development methods were introduced known as Agile Manifesto (Beck et al, 2001). Some of the most known agile software development methodologies are: Agile Unified Process (AUP) (Ambler, 2002), Extreme Programming (XP) (Beck, 2004) and SCRUM (Takeuchi and Nonaka, 1986; Beedle and Schwader, 2002).

Currently, software complexity is estimated using methodologies that based on size, such on counting Lines of Code (LOC)(Park, 1992), Functions Point Analysis (FPA)(Gamus and Herron, 2000; IFPUG), Counting Use Case Points (UCP)(Karner, 1993; Banrjee, 2001), COCOMO II (Boehm et al, 2000). Fitsilis et al (2010), state that size alone is not sufficient for measuring software project complexity, "since a large but well – structured software project with relaxed cost and time constraints can be much less complex in comparison with a relatively small-in-size project, which has a highly integrated product design and limited budget and/or time-to-market objectives". From the above it is obvious that in order to manage complexity in software projects, we should be able to combined principles from Project Management and Software Engineering using a flexible typology of complexity.

Complexity of Communication in Projects

According to Pinto and Pinto (1990), project communication can be defined as the vehicle through which project stakeholders share information from different functional areas that is essential to the successful implementation of the project.

A vital part of project team activities is communication as it can improve the team cooperation (Pinto and Pinto, 1990), coordination (Hauptman, 1990), information processing (Hinz, 1997), decision making (Poole and Hirokawa, 1996), knowledge sharing (Vries et al, 2006), team member activities (Oh, 1991).

Communication can be classified in three main categories according the project stakeholders, the type of message and the media used (Muller, 2003; Pinto and Pinto, 1990). From the perspective of the project

stakeholders, communication can be divided in internal and external. Internal is the communication between project team members such as administration, project managers and development teams whereas external is the communication with project team and project clients or public.

Communication Management as it is described in PMBOK (PMI, 2008) is a widely accepted way to reduce the probability of communication failures. It includes the following process:

- **Stakeholders Identification.** It refers to identification of all people or organizations impacted by the project, and to documentation of relevant information regarding their interests, involvement, and impact on project success.
- **Communications Planning.** It refers to determination of the project stakeholder information needs and to definition of a communication approach.
- **Information Distribution.** It refers to making relevant information available to project stakeholders as planned.
- **Stakeholder Expectations Management.** It refers to communication and work with stakeholders in order to meet their needs and addressing issues as they occur.
- **Performance Reporting.** It refers to collection and distribution of performance information, including status reports, progress measurements, and forecasts.

One of the biggest challenges in project management process is the co-ordination of people, processes and activities in projects. The mean to achieve this is communication (McChesney and Gallagher, 2004). Studies in Information Technology (IT) projects, such as The Standish Group 2005 and 2009, the "Why Software fails" (Charette, 2005) identifies communication failure or poor communication between project stakeholders, among the most important factors that affect project success. Although there are methods that describe practices, techniques and procedures such as the Yourdon System Method (Yourdon Inc, 1993), the Unified Software Development Process (Jacobson et al, 1999) in software engineering environment for coordinate software builds and version control the increasing complexity in software projects arising from the increasing demand for software systems, changes in software technologies and the increasing complexity of software functionality makes a lot of space for further development in coordination of project stakeholders and hence in the communication and communication management (McChesney and Gallagher, 2004).
It is generally accepted that complexity in communication is present on every aspect of communication process (McChesney and Gallagher, 2004; Saunders and Stewart, 1990; Bergen, 1987). In order to achieve an effective communication management, it is important to control this complexity. However to succeed that, communication complexity sources and measures should be determined. The most important communication complexity sources are summarized at the following list.

- **Nature of projects.** Refers to uniqueness, temporary and short life of projects teams that set up to achieve specific objectives (Diallo and Thuillier, 2005;Turner and Muller, 2003)
- **Project stakeholder properties.** Refers to stakeholder properties such as number, type, level of education, experience etc. (Diallo and Tuillier, 2005; Muller, 2003).

- **Project environment**. Refers to geographical distribution, technology changes, different first speaking languages, different cultures etc.(Daim et al, 2011; Lee-Kelly and Sankey, 2008; Dekker et al, 2008; Layman et al, 2006).
- **Communication structure**. Refers to the structure of organization communication processes, for example preferred type of communication, information distribution, feedback mechanisms, communication lines etc. (Daim et al, 2011; Dekker, 2008; Pinto and Pinto, 1990).
- **Communication properties**. Refers to properties of communication process such as frequency, duration, type and media used (Kennedy et al, 2011; Patrashkova and McComb, 2004; Muller, 2003; Sosa et al, 2002).
- **Physcical elements**. Refers to lack of clarity and logical structure of messages, unclear organizational structure, bad communication equipment etc (Carvalho, 2008; Backlund and Ronnback, 1999; Saunders and Stewart, 1990).
- **Psychological elements**. Refers to emotions and attitudes such as dislike of sender, lack of respect for the other party of communication, dogmatic attributes, trust etc.(Carvalho, 2008; McChesney and Gallagher, 2004; Saunders and Stewart, 1990).

Having located the communication complexity sources, the next step is to determine a set of measures for each complexity source to measure communication complexity. In our approach, our objective is to focus on measures that are mainly quantitative and can be measured at the beginning of the project. Our intention is to estimate the expected communication complexity and hence be able to take all the appropriate measures to control it.

Discussion

Project stakeholders' properties, as these are defined in the previous section, are considered as the most important complexity sources that affect communication complexity. Questions as the "number of project stakeholders", the "number of different teams" of project and the "number of different types of project teams" that will be formed, can give to project manager a very concise picture about project communication needs and can be used as metrics for the communication complexity of a project. As the number of stakeholders and teams grows up, the communication complexity is increasing because communication planning and processes become more complex and more resources are needed to put on communication activities. Meetings must be organized in way that all concerned team members be able to participate, but they cannot be numerous as it makes extremely difficult for everybody to express its opinion and finally decisions to be taken (Butler, 2001). Different types of project teams enhance complexity as they have different knowledge bases, motivations, reasoning abilities and thinking approaches (Daim et al, 2011). Another important factor arising from this complexity source is stakeholders' experience, as it can reduce or increase communication complexity since an experienced stakeholder doesn't need the same amount of information as an inexperienced one (Muller, 2003). Moreover an experienced employee can rely on email communication for example, to discuss most issues that arise during his work while an inexperienced one will require more face to face meetings. Thus question asking for that such as "Average project stakeholders' experience" would be an appropriate metric.

Projects nature refers to the temporary nature of project teams which is a factor that enhances communication complexity (Turner and Muller, 2003). Software development projects are operating in an environment of continuous changes with respect to the technology. These changes make difficult the reuse of solutions or software products in other projects and make important the employees continuous training and frequent renewal of human resources. Furthermore virtual teams that are geographically dispersed, increasingly more and more in high tech projects (Daim, 2011; Kozlowski and Ilgen, 2006). These project teams could not even exist if there was no strong communication infrastructure. In addition, geographical distribution of project teams adds complexity as new difficulties reveal in communication such as time differences, different mother languages or cultures (Lee-Kelly and Sankey, 2008). As these differences increase complexity increases as well. For example if projects teams are dispersed in three continents it is quite difficult to have synchronous communication such as videoconference or teleconference. These restrictions leads to use of other types of communications which in their turn increase or decrease complexity from other sources. So properties of project environment, as those just mentioned, play an important role in projects communication complexity. Therefore metrics exploring the degree of geographical distribution of project teams, existence of time differences, etc. are a necessity.

Bergen, (1987) refers that according to Lawrence and Lorchs' differentiation theory, the thinking of people are colored due to culture, educational, training and responsibility factors and for that reason they gain different impressions for the same data. Geographical distribution of projects as well as with the globalization of labor market (Lu et al, 2005), leads to formation of teams with people from different nationalities and hence with differences in culture, ethic, habits, education, training to say few (Dekker et al, 2008;Hardin et al, 2007). These are critical factors in arising of attitudinal and psychological barriers between team members (Fox, 2001). There are businesses that are dispersed all over the work which send employees, in critical positions, to other countries in order to understand the culture of people being there (Daim, 2011). Thus metrics exploring the differences in nationality of project stakeholders such as "Existence of project stakeholders with different nationality/culture", "Nationality distribution of project stakeholders" are necessary.

Team members, especially in virtual teams, have often difficulties to build trusted relationships with other team members and can be easily feel neglected (Daim, 2011). As such a communication based on email or reports will not be adequate as they increase the possibility of arising of misunderstandings and psychological or attitudinal barriers (Lee-Kelly, 2007). Research in email communication has noted that the use of inappropriate tone and words were very common (Biesenbach – Lucas, 2007). The need for more interpersonal communication media is intense. Furthermore, the use of more interpersonal communication media can reduce complexity sourcing from psychological elements such as defensiveness, lack in credibility or respect between team members, judgmental attitudes etc. Humans in their communication use more than one communication channels to convey a message, such as body language, voice tone, facial expressions and eye contacts. The messages received by these channels can totally differentiate the meaning of words spoken. Examples of communication media rich in communication channels are videoconference, face to face meetings, or telephone. The richer in communication channels is a media the more effective is in

communication (Maznevski and Chudoba, 2000) considering psychological and attitudinal factors (Burtha and Connaughton, 2004). However there are and disadvantages, as teleconference for example, cannot satisfy the need for clearance and clarity of requirements. There is a tug between different types of media in communication, as many times they contradicting each other in different aspects of communication efficiency. Therefore, the media type will be used in communication, is very important property of communication and metrics considering the availability and extends of use of each media type should be defined. Examples of such metrics can be "Availability of face to face media", "Availability of oral media", "Percentage of communication based on face to face media", "Percentage of communication based on written media", etc.

Characteristics - properties that can also affect communication performance are frequency and duration of communication. For example, too little communication can lead to confusion and misunderstandings and decrease on performance (Katz and Allen, 1982) whereas too much communication can lead to communication overload (Patroshkova and McComb, 2004) because members have limits in the amount of information they can process (Fussel et al, 1998; Boisot 1995). Both of these circumstances will lead to reduce of communication efficiency and hence team cohesion, performance and finally will lead to difficulties in project goal achievement. Studies have proven that the relation between performance and communication is curvilinear (Kennedy et al, 2011; Patroshkova et al, 2003; Huchins,1995). This implies that there is an upper bound in amount of communication in relation to team performance and beyond that the performance will decreased if communication increased. As such, metrics as "Average frequency of face to face communications", "Average duration of oral communication", "Number of emails", etc. are necessary.

In order to reduce communication issues that can arise, specific communication structures, processes and protocols must be defined (Carvalho, 2008). For example, specific communication lines across team stakeholders must be established, in order to set a structure in communication between stakeholders. If these lines are not established the control of communication will be lost, as messages will end pass from one to the other with no order, specific information may arrive at wrong persons etc. A prerequisite for establishing communication lines is the clear assignment of responsibilities in project members. These two actions are very important as everybody will know what should be communicated to whom and through which communication line. As a consequence metrics that explore these two actions such as "Clear assignment of responsibilities" and "Clear assignment of communication lines" can be useful in measuring complexity sourcing from communication structure of project team.

Summarizing all the aforementioned, we propose a set of communication metrics (see Table 1) based on communication complexity sources we have defined earlier. The table contains the metric name, the corresponding communication complexity source and a proposed evaluation method for each metric.

Table 1: Communication complexity metrics			
A/A	**Metric Name**	**Communication Complexity Source**	**Evaluation Method**
1.	Number of project stakeholders (Buttler, 2001)	Project Stakeholder	Likert scale from 1 to 5 (e.g. 1 for <=50 each number adds 50,5 for>= 250)
2.	Number of project teams (Muller,2003)	Project Stakeholder	Likert scale from 1 to 5 (e.g. 1 for <=3 each number adds 3, 5 for >= 15)
3.	Number of different type of project teams (Daim et al, 2011; Muller,2003)	Project Stakeholder	Likert scale from 1 to 5 (e.g. 1 for equal to 1 each number adds 1, 5 for equal to 5).
4.	Average project stakeholders' experience (Muller, 2003)	Project Stakeholder	Likert scale (Small, Quite small, Moderate, Rather large, Large).
5.	Geographical distribution of project stakeholders (Daim et al, 2011;Lee-Kelly and Sankey,2008)	Project environment	Likert scale (None, Slight distribution, Moderate distribution, Very distribution, Substantially distribution).
6.	Existence of time differences between project teams (Daim et al, 2011;Lee-Kelly and Sankey,2008)	Project environment	Likert scale ((None, Slightly, Moderate, Very, Substantially).
7.	Clear assignment of communication lines (Daim et al, 2011; Saunders and Stewart,1990)	Communication structure	Likert scale with scale from 1 to 5 (1 equal to no,5 equal to yes).
8.	Clear assignment of responsibilities (Daim et al, 2011; Carvalho,2008)	Communication structure	Likert scale with scale from 1 to 5 (1 equal to no, 5 equal to yes).
9.	Planned communication frequency (Patrashkova and McComb, 2004)	Communication properties	Likert scale (Very frequently, Occasionally, Rarely, Never).
10.	Expected average communication duration using written media (Patrashkova and McComb, 2004)	Communication properties	Likert scale (Very frequently, Occasionally, Rarely, Never).
11.	Expected average percentage of labor spent on communication (Patrashkova and McComb, 2004)	Communication properties	Likert Scale (Almost none, Some, Intermediate, A lot, Substantial).
12.	Distribution of nationality of project stakeholders (Lee-Kelly and Sankey, 2008)	Project environment	Likert Scale (None, Some, Intermediate, A lot, Substantial).
13.	Existence of project stakeholders with different culture (Daim et al 2011; Dekker et al, 2008)	Project environment	Likert Scale (None, Some, Intermediate, A lot, Substantial).

Conclusions

In today's world software projects are considered as the most demanding type of projects, as results from the number of software projects that fail to meet their requirements in terms of time delay, cost overruns and quality restrictions. According to our approach, increased complexity in these projects, arising from their nature, and lack of using project management methods are the reasons for these failures. In this paper we focus on project communication management and we attempt to identify the most important complexity sources for communication. Then we suggest a set of metrics for measuring communication complexity and try to reveal the connection between proposed metrics and communication complexity sources.

References

Ambler, S. (2002), Agile Modeling Effective Practices for Extreme Programming and the Unified Process, Wiley & Sons

Antoniadis, D. (2009), Thesis Title: Managing Complexity in Project Teams, Loughborough University

Baccarini, D. (1996), "The concept of project complexity – A review", *International Journal of Project Management,* **14**(4), pp. 201–204

Backlund, G. Ronnback, A.O. (1999), "Managing complexity in collaborative development: modeling requirements and enhancing communication", *Journal of Microprocessors and Microsystems,* **23**, pp. 409-416

Banerjee, G. (2001), Use Case Points-An Estimation Approach, [Online] Available at: <http://www2.fiit.stuba.sk/~bielik/courses/msi.../use_case_points.pdf> [Accessed: Dec. 10, 2010]

Bechtold, P. (1999), Essentials of Software Project Management, Management Concepts

Beck, K. (2004), Extreme Programming Explained: Embrace Change, 2nd edition, Addison Wesley

Beedle, M. Schwaber, K. (2002), Agile Software Development with SCRUM, Prentice Hall

Bergen, S. A. (1986), Project management in R&D Blackwell, UK

Boehm, B. Abts, C. Brown, A. W. Chulani, S. Clark, B. K. Horowitz, E. Madachy, R. Reifer, D. J. and Steece, B. (2000), Software Cost Estimation with COCOMOII, Englewood Cliffs N.J., Prentice Hall

Boisot, M. (1995), Information Space: A Framework for Learning in Organizations, Institutions, and Culture.Routlege, London

Bosch-Rekveldt, M. Mooi, H. Verbraeck, A. Sjoer, E. Wolsing, B. & Gulden, C. (2009), Mapping project manager's competences to project complexity, In K. Kakonen (Ed.), IPMA 23rd World Congress, Research Track Human Side of Projects in Modern Business. Helsinki: Project Management Association Finland (PMAF) and VTT Technical Research Centre of Finland

Brooks, F. P. (1995), No Silver Bullet: Essence and Accidents of Software Engineering, The Mythical Man Month, Anniversary Edition. Addison-Wesley

Burtha, M. Connaughton, SL. (2004), "Learning the secrets of long-distance leadership", KM Rev, **7**(1), pp. 24–7

Butler, S. B. (2001), "Membership Size, Communication Activity,and Sustainability: A Resource-Based Modelof Online Social Structures", *Information Systems Research,* **12**(4), pp. 346-362

Camci, A. and Kotnour, T. (2006), Technology complexity in projects: Does classical project management work? *PICMET 2006 Proceedings*, Turkey, pp. 2181–2186.

Carvalho, M.M. (2008), Communication issues in projects management. PICMET '08—2008 Portland International Conference on Management of Engineering & Technology, (c), pp. 1280–1284. doi:10.1109/PICMET.2008.4599739. Ieee

Charette, R. (2005), Why Software Fails, [Online] Available at: <http://spectrum.ieee.org/computing/software/why-software-fails>, [Accessed: Nov, 15, 2010].

Cooke-Davies, T. Cicmil, S. Crawford, L. Richardson, K. (2007), "We're not in Kansas anymore, Toto: mapping the strange landscape of complexity theory, and its relationship to project management", *Project Management Journal,* **38**(2), pp. 50–61

Daim T, Ha A. Reutiman S. Hughes B. Pathak U. Bynum W. Bhatla A. (2011), "Exploring the communication breakdown in global virtual teams", International Journal of Project Management, in press

Davidson, F.J. (2002), The New Project management, Wiley & Sons.

Dekker, D. Rutte, C. Van de Berg, P. (2008), "Cultural differences in the perception of critical interaction behaviors in global virtual teams", *International Journal of Intercultural Relations*, **32**, pp. 441-452

Diallo, A. Thuillier, D., (2005), "The success of international development projects, trust and communication: an African perspective", *International Journal of Project Management,* **23**, pp. 237-252

Dombkins, D. Dombkins, P. (2008), Contracts for Complex Programs: a Renaissance of Process, Booksurge Publishing, Charleston

Fitsilis, P. Kameas, A. and Anthopoulos, L. (2010), "Classification of Software Projects' Complexity", *Information Systems Development 2011*, Part 2, pp. 149-159, Springer

Fitsilis, P. and Stamelos, G. (2007), *Software Project Management*, Hellenic Open University Publications

Flyvbjerg, B. Bruzeliusm, N. Rothengatter, W. (2003), *Megaprojects and Risk*, An Anatomy of Ambition Cambridge University Press, Cambridge

Fox, S. *Effective communication: stone age to e-comm*. Proceedings of the Project Management Institute Annual Seminars & Symposium,USA, Nov. 2001

Fussell, S.R. Kraut, R.E. Lerch, F.J. Scherlis, W.L. McNally, M.M. Cadiz, J.J. (1998), *Coordination, overload, and team performance:effects of team communication strategies*. In: Proceedings of the 1998 ACM Conference on Computer Supported Cooperative Work. ACM, Seattle, WA, pp. 275–284

Gamus, D. and Herron, D. (2000), Function Point Analysis: Measurement Practices for Successful Software Projects, Addison-Wesley

Geraldi, J. (2008), "Patterns of complexity: The thermometer of complexity, Project Perspectives", *IPMA,* **29**, pp. 4–9

Geraldi, J. (2008), "The balance between order and chaos in multi-project firms: A conceptual model", *International Journal of Project Management,* **26**, pp. 348–356

Geraldi, J. and Adlbrecht, G. (2006), "On faith, fact, and interaction in projects", *Project Management Journal,* **38**(1), pp. 32–43

Hardin, A. M. Fuller, M. A. & Davison, R. M. (2007), "I know I can, but can we? Culture and efficacy beliefs in global virtual teams", *Small Group Research*, **38**, pp. 130–155

Hass, K. (2007), "Introducing the project complexity model", A New Approach to Diagnosing and Managing Projects—Part 1 of 2, PMWorld Today, **IX**(VII), pp. 1-8

Hauptman, O. (1990), "The different roles of communication in software development and hardware R&D: phenomenologic paradox or a theoretical empiricism?" *Journal of Engineering and Technology Management,* **7**, pp. 49-71

Hinsz, V. Tindale, R. Vollrath, D. (1997), "The emerging conceptualization of groups as information processors", *Psychological Bulletin,* **121** (1), pp. 43–64

Holmes, A. (2001), Failsafe IS. Project delivery, Aldershot: Gower.

Hughes, B. Cotterell, M., 1999, Software Project Management, McGraw Hill

IFPUG (International Function Point Users Group), [Online] Available at: <http://www.ifpug.org/> [Accessed: Dec. 10, 2010]

IPMA, 2006, IPMA Competence Baseline, Version 3.0. Van Haren Publishing

IPMA, 2008, IPMA Competence Baseline, Version 4.0. PMI Publishing
Jacobson, I. Booch, G. Rumbaugh, J. (1999), The Unified Software Development Process, Addison-Wesley, Reading, Massachusetts
Karner, G. (1993), Metrics for Objectory, Diploma thesis, University of Linkoping, Sweden.No. LiTH-IDA-Ex-9344:21
Katz, R. Allen, T.J. (1982), "Investigating the not invented here (NIH) syndrome: a look at the performance, tenure, and communication patterns of 50 R&D project groups", *R&D Management,* **12** (1), pp. 7–20
Kennedy, D.M. McComb, S. Vozdolska, R.R. (2011), An investigation of project complexity's influence on team communication using Monte Carlo simulation
Kiountouzis, E. (1999), Software Project Management, Stamoulis Publishing
Kozlowski, S. W. J. & Ilgen, D. R. (2006), "Enhancing the effectiveness of work groups and teams", *Psychological Science in the Public Interest*, **7**, pp. 77–124
KPMG, (2003), KPMG's international 2002–2003 Programme Management Survey, [Online] Available at: <http://www.kpmg.com.au/Portals/0/irmprm_pm-survey2003.pdf>, [Accessed: Dec. 10, 2010]
Laird, L. and Brennan, M. (2006), Software Measurement and Estimation, A Practical Approach, John Wiley and Sons
Layman, L. Williams, L. Damian, D. Bures, H. (2006), "Essential communication practices for Extreme Programming in a global software development team", *Information and Software Technology,* **48**, pp. 781-794
Lee, O. (2002), "Cultural differences in email use of virtual teams: a criticalsocial theory perspective", *CyberPsychol Behav*, **5**(3), pp. 227–32
Lee-Kelley, L. Sankey, T. (2008), "Global virtual teams for value creation and project success: a case study", *International Journal of Project Management,* **26** (1), pp. 51–62
Lu, M. Watson-Manheim, M. M. House, C. H. & Matzkevich, T. (2005), Does distance matter? Bridging the discontinuities in distributed organizations, HICSS, 2005
Maylor, H. Vidgen, R. Carver, S. (2008), "Managerial complexity in project based operations: a grounded model and its implications for practice", *Project Management Journal,* **39**, S15–S26 Supplement
Maznevski, ML. Chudoba, KM. (2000), "Bridging space over time: global virtual team dynamics and effectiveness", *Organ Sci*, **11**(5), pp. 473–92
McChesny, I.,Gallagher, S. (2004), "Communication and co-ordination practices in software engineering projects", *Information and Software Technology,* **46**, pp. 473–489
Meredith, J. Mantel, S. (2008), Project Management: A Managerial Approach 7th edition, Wiley & Sons
Morris, P.W.G. Hough, G.H. (1987), The Anatomy of Major Projects: a Study of the Reality of Project Management, John Wiley, Chichester
Muller, R. (2003), "Determinants for external communications of IT project managers", *International Journal of Project Management,* **21**, pp. 345–354
Neleman, (2006), Shell gaat diep, FEM Business **9**(4), pp. 30–34
Oh, K. Kim, Y. Lee, J. (1991), "An empirical study of communication patterns, leadership styles, and subordinate satisfaction in R&D project teams in Korea", *Journal of Engineering and Technology Management,* **8**, pp. 15-35
Park, R. (1992), Software size measurement: A framework for counting source statements, Carnegie Mellon University, CMU/SEI-92-TR-020 [Online]. Available at: http://www.sei.cmu.edu/pub/documents/92.reports/pdf/tr20.92.pdf>, Accessed: Dec. 10, 2010]
Parwani, R.R. (2002), Complexity: an Introduction, National University of Singapore, Singapore
Patrashkova, R. McComb, S.A. Green, S.G. Compton, W.D. (2003), "Examining a curvilinear relationship between communication frequency and team

performance in cross-functional project teams", *IEEE Transactions on Engineering Management,* **50**(3), pp. 262–269
Patroshkova, R. McComb, S. (2004), "Exploring why more communication is not better: insights from a computational model of cross-functional teams", *J. Eng. Technol. Manage*., **21**, pp. 83–114
Paulk, M. et al, (1995), The Capability Maturity Model: Guidelines for Improving the Software Process, Addison-Wesley Professional
Pinto, M. Pinto, J. (1990), "Project team communication and cross-functional cooperation in new program development", *Journal of Product Innovation Management,* **7**(3), pp. 200–212
PIPC, (2005), Global project management survey, [Online] Available at: <http://www.pmportal.co.uk/uploads/documents/PIPCSurvey.pdf>,[Accessed: Dec. 10, 2010]
PMI Institute, (2004), A Guide to the Project Management Body of Knowledge, PMI Standard Committee
Poole, M. Hirokawa, R. (1996), Introduction: communication and group decision making. In: Hirokawa, R., Poole, M. (Eds.), Communication and Group Decision Making. Sage, Thousand Oaks, CA, pp. 3–18
Saunders, R.G. Stewart, R.W. (1990), "Failure of communication in research and development", *Journal of Project management in R&D,* **2**(8)
Simon, H. (1962), The architecture of complexity, Proceedings of the American Philosophical Society
Sosa, M. Eppinger, S. (2002), "Factors That Inflience Technical Communication in Distributed product development: An Empirical Studey in the Telecommunications Industry", *IEEE Transactions on Engineering Management*, **49**(1)
SWBOK, (2004), Guide to the Software Engineering Body of Knowledge , [Online] Available at: http://www.computer.org/portal/web/swebok/about >,[Accessed: Dec. 10, 2010]
Takeuchi, H. Nonaka, I. (1986), The New Product Development Game, Harvard Business Review
Thamhain, H.J. Wilemon, D.L. (1986), "Criteria for controlling projects according to plan", *Project Management Journal,* **17**(2), pp. 75–81
The Standish Group, (1995), Charting the Seas of Information Technology—Chaos. West Yarmouth, MA: The Standish Group International
The Standish Group, (2009), CHAOS Summary 2009 The 10 Laws of CHAOS, The Standish Group International [Online] Available at: < www.statelibrary.state.pa.us/portal/server.pt/.../chaos_summary_2009_pdf >, [Accessed: Dec. 10, 2010]
Turner, J. R. Muller, R. (2003), "On the nature of the project as a temporary organization", *International Journal of Project Management,* **21**(2003), pp. 1–8
Vidal, L.-A. Marle, F. (2008), "Understanding project complexity: implications on project management", *Kybernetes,* **37**(8), pp. 1094–1110
Vries, R. van den Hooff, B. de Ridder, J.A. (2006), "Explaining knowledge sharing: the role of team communication styles, job satisfaction, and performance beliefs", *Communication Research,* **33**, pp. 115-135
Whitty, S.J. Maylor, H. (2009), "And then came Complex Project Management (revised)", *International Journal of Project Management,* **27**(3), pp. 304–310
Williams, T. (2002), Modeling Complex Projects, Wiley, Chichester
Williams, T.M. (1999), "The need for new paradigms for complex projects", *International Journal of Project Management,* **17**(5), pp. 269–273
Williams, T.M. (2002), Modeling Complex Projects, John Wiley & Sons, London
Williams, T.M. (2005), "Assessing and moving on from the dominant project management discourse in the light of project overruns", *IEEE Transactions on Engineering Management,* **52**(4), pp. 497–508
Xia, W. Lee, G. (2004), "Grasping the complexity of IS development projects", *Communications of the ACM,* **47**(5), pp. 69–74

Xia, W. Lee, G. (2005), "Complexity of information systems development projects: conceptualization and measurement development", *Journal of Management Information Systems,* **22**(1), pp. 45–83

Yourdon, Inc. (1993), Yourdon Systems Method, Prentice Hall, Englewood Cliffs, NJ