The Nature of the Relationship between Project Complexity and Project Delay:

Case study of ERP system implementation projects

Authors: Maksim Miterev
Ruxandra Nedelcu

Supervisor: Professor, Dr. Ralf Müller

Student
Umeå School of Business and Economics
Autumn semester 2011
Master thesis, one-year, 15 hp

ACKNOWLEDGEMENTS

Our first words of appreciation go to Professor Ralf Müller, who supervised the present Master thesis. He always promptly provided us with feedback, encouraged us to go an extra mile and most importantly helped us at the critical junctions of the research project.

We are immensely thankful to the project managers and senior consultants of ERP implementation projects, who agreed to participate in interviews and spent their valuable time to fill in questionnaire. In particular, we are grateful to Andrey Nechpai, Manager at Deloitte; Konstantin Blumental and Alex Ternaus, both Senior Consultants at IBM Consulting; as well as to other interviewees who have preferred not to disclose their names. The study would not be possible without their participation, which is deeply appreciated.

We would like to express our gratitude to all lecturers in Heriot-Watt University (Scotland), Politecnico di Milano (Italy) and Umeå University (Sweden) who shared their knowledge with us and supported our personal development. Special thanks go to Amos Haniff, Antonio Calabrese and Tomas Blomquist for the coordination of the program, which has become indeed a life-changing experience for us.

We would also like to sincerely thank the European Commission, which generously made our participation in the program possible by granting us financial support.

ABSTRACT

In the context of a growing social complexification, projects have evolved in the past decades from simple endeavours to complex and uncertain undertakings. Consequently, project complexity has emerged as an important research direction, and recently several project complexity frameworks have been suggested. However, little research has been done in this area and there has been no study on the relationship of project complexity, in its holistic sense, and the risk of delay. Therefore, the study investigates the intricate relationship between project complexity and project delay. The research is conducted in the context of Enterprise Resource Planning system (ERP) implementation projects, which are inherently complex and often record delays.

The study has a qualitative nature and adopts an inductive approach. Nine ERP-implementation projects have been studied in order to answer the research question. Several sources of evidence (semi-structured interviews and questionnaires) have been utilized to ensure the credibility of the research findings through triangulation.

The study contributes to the research field by verifying and augmenting the existing frameworks on reasons for project delay, complexity categories and their interplay. It was identified that complexity in a holistic sense represents a necessary condition for project delay. Moreover, the study showed that although ERP projects are often considered to be technically complex, their complexity stems mainly from ‘subjective’ (or perceived) and ‘uncertainty’ complexity dimensions. Finally, the conceptual model of Eden et al. (2005) was modified to reflect the findings of the study.

Keywords: *Complexity theory, Project complexity, Project delay, Reasons for delay, ERP implementation, Project risk.*

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1 – INTRODUCTION

1.1. Background

During the past several decades, projects have become so widespread, that some scholars claimed that 'projectification' of society has occurred (Midler, 1995; Lundin & Söderholm, 1998; Maylor et al., 2006, p. 664). Thus, although during the early years project management was practiced only in a limited number of industries, most notably defence, construction and engineering, it has become widely spread in all fields in the past years (Grabher, 2002, p. 206; Winter et al., 2006, p. 638). Furthermore, according to Van Der Merwe (2002, p. 402) projects seem to lie at the foundation of the modern organizations. There are a number of powerful driving factors behind the trend of projects proliferation (Gray & Larson, 2008, pp. 7-11): the necessity for faster product development due to pace of technology change, product life-cycle compression and increasing competition; the need for an effective management response to the growing market fragmentation as opposed to the 'mass production era'; and the demand for more efficient communication among smaller teams of diverse backgrounds spread all over the world.

In the light of these changes in the business environment, not only have projects become pervasive in the past decades, but have also evolved from simple undertakings to complex and uncertain endeavours (Laufer et al., 1996, cited in Williams, 1999a, p. 272). Thus projects have become risky undertakings, and complexity plays an important role in this, since according to Vidal & Marle (2008, p. 1101) "project complexity is the property of a project which makes it difficult to understand, foresee and keep under control its overall behaviour".

In the context of an increasing project complexity that leads to nonlinear and unpredictable outcomes (Maylor et al., 2008, p. S16), the traditional project management methods, which are underpinned by the deterministic model, focusing on planning and control, have shown their limitations (Winter et al. 2006, p. 640). Therefore, the classic triangle of parameters time, cost and quality are no longer sufficient to reflect the reality of projects, failing to grasp their complex nature (Jaafari 2003, Williams, 1999, cited in Vidal & Marle, 2008, p. 1095). Consequently, in the context of a preponderance of tayloristic "one size fits all" approaches in the field of project management, which disregard the growing and lately omnipresent complexity that characterizes projects, the number of project overruns is higher than ever. In this respect, using a System Dynamics approach, Williams (2005) showed that "by taking actions that are implied or suggested by conventional methods (i.e. according to various bodies of knowledge) in order to try to deal with late-running projects, managers themselves are exacerbating the feedback and making the overruns worse" (p. 499). Thus, there has been a staggering rate of project overruns in the light of failures in project predictability and management (Thomas & Mengel, 2008, p. 304).

One of the fields where the traditional project management methods constantly fail to fulfil their purpose is the IT industry, where projects are often regarded as complex, dynamic and contextualized endeavours (Lee et al., 2007, p. 1). This has been further supported by the emergence of 'lean' and 'agile' project management, which is especially common in the IT industry, due to the particular goal-uncertainties of such projects (Cicmil et al., 2006, p. 683).

Particularly the Enterprise Resource Planning (ERP) system implementation projects have recorded astonishing high failure rates, almost three quarters of the implementations being deemed unsuccessful, with an average 178% budget overrun, taking 2.5 times longer than expected and realizing as low as 30% of promised benefit (Zhang et al., 2005, cited in Basoglu et al., 2007, p. 74). Furthermore, the ERP projects are highly complex systems, as they represent "a particular type of IT system covering most information-rich tasks in an organization: order management, production and material planning, inventory control, budgeting, HR management, accounting, customer data management etc" (Baraldi et al., 2009, pp. 24-25). Thus ERP projects employ a high number of resources, multiple interdependencies between system elements and a high degree of customization, each project having its own particularities that bring elements of novelty. Furthermore, given the high stakes entailed, ERP projects are often surrounded by high pressure from stakeholders and various conflicting interests.

1.2. Practical and theoretical motivations for the study

From a practical perspective, in view of the presented discussion, it is particularly important for project managers to understand the relationship between project complexity and project performance in order to manage projects successfully. Given the growing emphasis on time performance, in the light of opportunity window contracting, time-based competition and shorter time-to-market, understanding the impact of project complexity on project delay is of paramount practical importance.

Theoretical motivation for the study is two-fold. Firstly, there is a lack of empirical studies on project complexity in the literature (Vidal et al., 2011), and particularly, the connection between project complexity and delay is not well understood. Moreover, existing models of complexity are 'one-size fits all' generic models and to the best of our knowledge there is no comparison of suitability of different complexity models for different contexts (even though many authors argue that the concept is context specific). Secondly, project complexity was claimed to be one of the perspective future directions of project management research, thus highlighting the importance and actuality of the field (Winter et al., 2006, pp. 642-643). The research direction is associated with a shift from the rational deterministic models to a more holistic perspective from the social theory (ibid, p.643), since projects are complex social settings, characterized by unpredictability (Cicmil et al., 2006, p. 676).

1.3. Positioning of the study

In the past two decades, researchers started to go beyond the study of formal models within the "instrumental approach" (Cicmil et al., 2006, p. 676). This resulted in a scientific rethinking of project management, leading to a significant shift from understanding the project as a production function to a more holistic view (Turner & Müller, 2003, pp. 2-5).

This shift was also translated in the project complexity literature. Whereas the early papers focused on a narrow set of complexity elements (i.e. Baccarini, 1996; Shenhar & Dvir, 1996; Williams, 1999a; Jaafari, 2003; Xia & Lee, 2005), the more recent articles adopted a comprehensive understanding of project complexity (i.e. Geraldi & Adlbrecht, 2007; Remington & Pollack, 2007; Maylor et al., 2008; Vidal & Marle 2008; Bosch-Rekveldt et al., 2011; Geraldi et al., 2011). However, most of the studies are solely concerned with the development of complexity frameworks. While several authors acknowledge the importance of influence of project complexity on project performance, no direct linkage between complexity, in its holistic sense, and project delay has been developed, arguably because the application of complexity theory to project management is only an emerging stream of research.

Furthermore, this aspect was not covered in the literature on project delay, although many articles on the topic were published in the past years. While some of the complexity dimensions do appear in the studies (e.g. changed orders (Koushki et al., 2005; Assaf et al., 1995), resources shortage (Faridi & El-Sayegh, 2006; Sambasivan & Soon, 2007), design complexity, (Toor & Ogunlana, 2008), lack of experience (Lim & Mohamed, 2000; Sambasivan & Soon, 2007), lack of communication (Sambasivan & Soon, 2007)), they are scattered across different publications and the holistic perspective is not covered.

Therefore, to the best of our knowledge, no study has been conducted on the intricate interplay between holistic complexity categories and reasons for project delay and hence, it was chosen as the focus of the present study. Furthermore, it was decided to focus the study on ERP system implementation projects, since they represent a suitable context, being inherently complex and often recording delays.

1.4. Research question

Therefore, on the basis of the discussion presented above, the research question of the study was formulated: **"What is the nature of the relationship between project complexity and the risk of delay? (In the ERP-systems implementation projects context)"**

The unit of analysis of the research is the relationship between project complexity elements and the reasons for project delay.

In order to illuminate the topic several aspects have to be considered in the study: (1) How is complexity defined in the literature? (2) What are the project complexity dimensions and factors? (3) How do they influence project performance (especially in terms of time)? (4) What are the specific features of ERP-implementation projects influencing the relationship between complexity and delay?

1.5. Research objectives

The study aims to fulfil the following objectives:

a) Highlight peculiarities of the ERP-system implementation projects and their implications on project complexity dimensions in the research context
b) Explore the relationship between different project complexity dimensions and parameters and the reasons for project delays
c) Identify potential research areas.

1.6. Research process

The study adopts an interpretivistic stance to reflect the importance of soft factors in relation to complexity (Baraldi, 2009). In order to answer the research question, a case study strategy will be pursued as it allows researchers to perform an in-depth study by collecting evidence from multiple sources. Therefore, the relationship between project complexity and project delay will be analyzed from various angles. In order to achieve this, the semi-structured interviews will be complemented with a questionnaire survey allowing triangulation of findings. Given the topic and the context of the research, the selected interviewees are project managers and senior consultants from the IT industry, who have previously managed ERP implementation projects that have recorded delays.

The collected data will be analysed via a template analysis approach, in which data will be categorised according to complexity and delay templates, developed on the basis of the most recent reviews in the literature. In the end, the findings of the research will be compared with other similar studies and a conceptual model will be proposed that will underpin the relationship between project complexity and project delay.

1.7. Outline of the study

In the present ***Chapter 1*** the overall background of the research question is briefly presented.

Chapter 2 presents a literature review, which gives an overview of the overall scientific context for the research question, develops a theoretical frame of reference and helps to find the knowledge gap and position the study against the existing literature in the problematisation section.

Chapter 3 is devoted to the explanation of the research methodology. This includes both theoretical methodology, that is philosophical considerations underpinning the study (ontological and epistemological perspectives), and the research design, including discussion on the type of data, appropriate research strategy and corresponding data collection and analysis methods. This is complemented by the discussion of reliability and validity of the study along with measures undertaken to ensure both.

The analysis of the collected data is represented in ***Chapter 4***, following the methods described in the methodology to scrutiny sampled projects in order to reveal the relationship between complexity and project delay.

Chapter 5 contains the discussion of the research findings. Special attention is paid to the comparison of the results obtained with the existing research publications. Further, a conceptual visual model is developed based on the research findings.

Finally, ***Chapter 6*** draws the conclusion of the study, focusing on its theoretical and practical implications. The study is concluded with the delineation of the limitations of the research and the potential future lines of inquiry.

The **A*ppendices*** include the materials that have been used in the data collection process (the list of interview questions and the questionnaire) and the complete array of information that was extracted from the interview transcripts and questionnaires, which is referred to in the ***Chapter 3*** and ***Chapter 4***.

CHAPTER 2 – LITERATURE REVIEW

2.1. Introduction

The literature review chapter represents a very important part of the thesis, as it lays down the foundation for the following analysis. The chapter has several goals: Firstly, it aims to describe the overall research context for the topic and briefly outline the research streams in project risk management. Secondly, it aims to develop the frame of reference from the literature in the field, against which the presented research will be positioned. In order to fulfil this, specific concepts comprising the research topic and current advancements in the field are discussed in a detailed way. In the discussion, different scholars' viewpoints are described, definition of the main concepts used in the thesis is provided and critical overview is presented. Consequently, the ultimate goal of the chapter is the problematisation of the field.

The literature review is divided into several sections corresponding to interconnected topics related to the thesis research focus. After stating the literature selection approach, a short discussion of two different approaches in the project risk management field is provided to form a wider context for the topic. Then, the concept of project complexity, central to the thesis topic, is scrutinized. This includes overview of general complexity theory, comparison of different definitions in the field, discussion of project complexity dimensions and existing approaches to 'capture' complexity in a set of parameters. This is followed by theoretical and philosophical views on the intricate relationship between complexity, uncertainty and risk, which are underpinning the study. The following section overviews scarce empirical studies on how complexity influences project performance, with a focus on delay. The subsequent section presents existing approaches to estimate project completion date, since delays are always stated against certain reference points. Finally, ERP implementation projects are scrutinized with a focus on reasons for project failures, including delays. All the sections described are used then to identify knowledge gap in the research area and to position the study.

2.2. Literature selection approach

In order to conduct the research on the relationship between complexity and risk of project delay, we have decided first to gather an extensive list of articles that would be relevant for our topic. Thus we have defined the search criteria for each area of interest outlined above (e.g. we used the key words: "project complexity", "complex projects" and/or "risk of delay", "project overrun", "project delay" to find articles related to the influence of complexity on project delay) and we browsed scientific databases that covered Project Management and Operations Research areas (e.g. Ebsco, ScienceDirect, Springer, JSTOR, Emerald). The peer-reviewed journals were given first priority, and were complemented with Ph.D. theses, monographs and conferences' proceedings. Other sources were also included to strengthen specific areas. For example, publications of the practitioners' associations and reports of public institutions and industrial associations were considered, especially with regard to data on project performance, since this information was deemed to be factual and valid. In some cases such publications also helped to clarify usefulness of the suggested research for practitioners.

From the list of papers found we had done a pre-screening, by looking at abstracts, introductions and conclusions and choosing the articles and conference papers that seemed relevant for our topic. Considering the chosen research area, the most relevant articles were from the International Journal of Project Management, the Project Management Journal, the European Journal of Operational Research, the Journal of Construction Engineering and Management, the IEEE Transactions on Engineering Management and the Technology Analysis & Strategic Management journal.

Further, the analysis of reference lists of the selected articles was used to identify relevant sources which were not found using the search words. The reviews have proven to be most useful in this respect and helped to ensure completeness of the bibliography.

2.3. Overview of the project risk management

Project risk management is an inherently multi-disciplinary field, which needs inputs from management and operations research scientists to develop the theory, practitioners to make estimates and behavioural scientists to understand and correctly interpret the practitioners' estimates (Williams, 1995, p.18). Overall, there are two major streams of research on project risk management. The first stream is rooted in operations research (OR) field and aims to study formalised project models by mathematical means (Tavares, 2002). The second is attempting to incorporate 'soft side' of projects and calls for more holistic, though less formalised approach (e.g. Jaafari, 2001, 2003). Since these approaches represent two quite distinct worldviews and approaches to study the problem, they should be described in more detail.

The operations research approach studies projects as models. The models are defined in mathematically strict sense that allows studying them by applying existing approaches from pure and applied mathematics (which are well-developed for various applications in engineering and natural sciences). The system and all the relevant factors are assumed to be known, at least in the stochastic sense. Consequently, consideration is given only to the characteristics that can be expressed explicitly with a set of numerical parameters. The variety of wider methods of the OR field has been found to be applicable for the study of project models, such as various optimisation algorithms, dynamic programming, stochastic modelling, graphs, decision theory and game theory to name a few. The OR approach has developed broad applications for the PM (Tavares, 2002, p.2), such as various scheduling problems, quantitative risk analysis, competitive bidding models, portfolio management techniques (especially, project selection and portfolio optimisation), estimates of parameters and evaluation of project success. The output goes in form of generalized law-like principles that are claimed to be widely applicable.

Historically, the development of project management field was strongly connected to this line of thought and according to Tavares (1999, p.510) "the development of Project

Management is directly dependent on significant advances achieved in the area of modelling to produce efficient scientific representations of projects". In his later work Tavares (2002, p.2) goes further claiming that "the significant methodological advances to support PM ... have been mainly offered by OR [Operations Research]". However, although such approach is an 'exact' one and technically easy to transfer (e.g. through implementation in project management software) the main concern with it is that the reality could not be represented good enough if the implicit and soft side of projects is omitted or if there are unrealistic assumptions made about the system parameters (Williams, 1999b). Other important limitations are that managerial efforts are typically overlooked in the models (since they are assumed to be 'passive systems'), the models themselves are overly simplistic and linear and that the models are often not empirically grounded or verified.

In the past two decades, researchers started to go beyond studying formal models. This development concurred in time with proliferation of the project beyond traditional PM domains of construction, engineering and defence industries (Winter et al., 2006, p.638). Projects in these industries were often more formalised and developed, technically oriented, easily controllable through tangible outputs and less volatile, which suited the OR approach better. This has changed when projects became associated with business transformation, M&A, product development and innovation. Consequently, many traditional processes, tools and techniques have shown their limits (Vidal & Marle, 2008, p.1095). This resulted in a scientific rethinking of project management leading to a significant shift from understanding the project as a production function to a more holistic view of it as a temporary organization and an agency for change, resource utilisation and uncertainty management (Turner & Müller, 2003, pp.2-5).

The same shift (from 'hard' to 'soft' dimension) has occurred in project risk management field. That is, instead of studying stochastic networks, researchers started concentrating more on sources of risk, uncertainty and risk perception. The major research streams in the field include risk management processes organization (identification, assessment, monitoring etc.), risk allocation in contracts, data elicitation from experts and risks' influence on project success (predominantly in terms of time, cost and performance). Examples of recent more 'technical' advancements in the project risk management field include application of fuzzy logic (e.g. Zeng et al., 2007), Bayesian systems (e.g. Adams, 2008) and causal loops and systems dynamics techniques (Williams, 2003).

There are two main views on probability underpinning discussion of difference between risk and uncertainty (Williams, 1995, p.24). One, 'aleatoric', corresponds to inherently uncertain situation, and another, 'epistemic', relates to measure of belief and corresponds to imperfect information about the phenomena in question. These two views require different approaches and attitudes to tackle them as well as associated with notions of 'objective risk' and 'subjective perception of risk' correspondingly. In line with the pronounced difference "Wynne (1992) … [distinguishes] between risk (where the 'odds' are known), uncertainty (where the odds are not known, but the main parameters may be), ignorance (where we don't know what we don't know) and indeterminacy" (Williams, 1995, p.24). Most of the techniques associated with the traditional risk management are related to the first type of probability and uncertainty. However, the growing complexity, dynamics and uncertainty of projects imply that the research community should pay more attention to the other aspects.

2.4. Complexity

2.4.1. General complexity theory

'Complexity' is a concept widely used, not only in everyday life, but also in almost all fields of science. The notion of complexity can be found in biology, mathematics, physics, computation, logic, economics, software design, philosophy, general systems, management science, psychology and linguistics (Edmonds, 1999, p.18). The inter-disciplinary (or even trans-disciplinary) character of the concept is clearly reflected in the Springer Complexity publishing program devoted to fundamental and applied studies on the concept across all fields. To name a few, the publications in the series include contributions from engineering, economics, medicine, neuroscience, social and computer science (Bertelle et al., 2009). Consequently, the applications of the complex systems are very diverse and include the climate, the coherent emission of light from lasers, chemical reaction-diffusion systems, biological cellular networks, the dynamics of stock markets and internet, earthquake statistics and predictions, freeway traffic, the human brain or the formation of opinions in social systems (ibid). However, growing understanding that we live in a world of complexity caused several negative consequences, i.e. the concept is often misused or overused to claim a scientific work in a desirable field (Edmonds, 1999, p.17).

The field contains, albeit not limited to, several lines of inquiry, such as "self-organization, nonlinear dynamics, synergetics, turbulence, dynamical systems, catastrophes, instabilities, stochastic processes, chaos, graphs and networks, cellular automata, adaptive systems, genetic algorithms and computational intelligence" (Bertelle et al., 2009, front matter). From this list at least several themes can be strongly related to project management, e.g. graphs and networks, stochastic processes, genetic algorithms and self-organization, which emphasizes the promising connections between project management and general complexity theory fields.

Given such a diversity of applications it would be surprising if there would exist coherent understanding of the concept across all the fields and applications. On the contrary, complexity is a multi-faceted notion and can mean different things in different contexts (e.g. Schlindwein & Ison, 2004, p. 27) since "at the moment, apart from systems theory, models of complexity tend to be formulated with quite specific purposes in mind" (Edmonds, 1999, p.19).

These issues as well as the potential synergy of sharing complexity-related knowledge across different fields led to a call for the development of general yet formalised complexity theory (Casti, 1992, p.10), which is still in its initiation phase, given the vast variety of different (and often, contradictory) meanings and definitions attached to the concept (Schlindwein & Ison, 2004, p. 28). This can be illustrated by the notion of Edmonds (1999, p. 19) that "...there are only vague and unformalised connections between such models developed in different fields. This must impede progress and mean that there is needless repetition".

2.4.2. Different meanings of complexity

The concept of complexity is indeed complex in itself and researchers have approached its study from various perspectives. Some of these perspectives as well as the relationship of the concept to uncertainty and probability are outlined in the following discussion.

It is very important to separate two concepts, namely "complex system" and "complicated system" (Cotsaftis, 2009, p.3), which may look similar at first sight. The author draws distinction between the systems referring to the words origin, i.e. complex origins from Latin "cum plexus", which means "tied up with" implying interaction and interrelation, whereas complicated originates from Latin "cum pliare", meaning "piled up with", implying separability and favouring reductionism approach (Schlindwein & Ison, 2004, p.28; Cotsaftis, 2009, p.3). This helps understand Edmonds (1999, p.157) proposition that "size seems not to be a sufficient condition for complexity". The notion that size is insufficient condition for complexity is also illustrated in the paper of Cotsafis (2009, p.4) where the author discusses typical complex systems in physics which are too large to be analysed with classical mechanics equations but at the same time *not large* or stable *enough* to exhibit equilibrium thermodynamical properties since convection is still important.

According to Rescher (1998, cited in Schlindwein & Ison, 2004, p.29) there are three distinct 'modes' of complexity, i.e. epistemic, ontological and functional. The discussion on the nature of complexity is taken further by Schlindwein & Ison (2004, p. 27), who underlined the connection between different understanding of the concept with contrasting epistemologies ("epistemological problem of complexity"). The authors called to distinguish between the categories of descriptive and perceived complexity (ibid). The former considers complexity as a property of certain systems, and the latter claims inevitable subjectivity of any notion on complexity as a perception of a human being. The latter follows the viewpoint that the complexity is an inherently subjective matter, which is clearly expressed in the assertion of Casti (1992, p.10) that "complexity resides as much in the eye of the beholder as it does in the structure and behaviour of a system itself". For us, similarly to Schlindwein & Ison (2004, p. 30) understanding the subjective perspective does not mean rejection of the objective part, but instead understanding its limitations by "... reintroduction of the role of the observer into the explanations about complexity" (ibid).

An extensive review reveals 48 different formulations (either definitions or specification of properties) of the term existing in all fields of human knowledge (Edmonds, 1999, pp.136-163). These include understanding of the concept in terms of many different categories such as size, connectivity, ease of decomposition, non-predictability, irreducibility, probability, variety, stochastic properties and various forms of logical, computational, algorithmic and arithmetic definitions to name a few. Given such a variety caused by specific features of many application fields, it is especially important to identify main properties, which may form foundation for the understanding and definition of the concept.

The founding editor of the "Understanding Complex Systems" series of the Springer publisher, J.A. Scott Kelso, in the preface to the series, distinguishes two main dimensions of complexity: (1) composition, meaning that many diverse elements are interacting non-linearly and (2) diversity in behaviours, which is produced by the interaction. Similarly, Karsky (1997, cited in Vidal, 2009, p.17) propose three categories of complexity: spatial complexity (number, variety and interrelation between elements), unpredictable complexity, and dynamic complexity (impossibility to analyse evolution of a system, because of unknown feedback loops in time). This seems to be in line with Kelso's dimensions as both unpredictability and dynamics lead to diversity in behaviours.

The unpredictability seems to be underlined by almost all authors in the field. For example, Cotsaftis (2009, p.4) links the complexity concept to "the great difficulty in predicting their future behaviour from an initial instant", thus underlining the property (unpredictability) of the complex systems. Similarly, Grassberger (1989, cited in Edmonds, 1999, p.72) considers complexity as a "difficulty" to formulate behaviour of systems.

Due to the pronounced connection to the complex systems' uncertainty in behaviour, it is important to discuss the relationship between level of knowledge, complexity and uncertainty. The difficulty to predict the behaviour of a system may come from two main sources, lack of information or knowledge about the system in question or the genuine complexity and it is very important to distinguish between them (Edmonds, 1999, p.79). As he puts it "you can only reliably attribute complexity to a system when there is a possibility of knowing a reasonable amount about its components, otherwise the apparent difficulty of formulation might be merely due to some simple but unknown mechanism" (ibid).

Further, the connection between complexity and uncertainty is far from decided upon in the literature. For instance, Schlindwein & Ison (2004, p.28) claim that uncertainty is linked to complexity, although the linkage is not explained in the paper and even its causal direction is questionable. In line with this ambiguity and perhaps in explanation of it, Edmonds (1999, p.148) asserts that "the connection of probability and complexity is intricate" and strongly depends on the field of application and on the adopted definition. For instance, if complexity is understood in terms of entropy or algorithmic measures, then it relates to high probability. On the other hand, if the concept corresponds to the system's arising by chance, then complexity relates to low probability.

There is also no agreement in the literature on whether the complexity is a positive, negative, neutral feature or any of these depending on context. For instance, a notion of difficulty has been associated with the concept of complexity, implying its negative nature (Edmonds, 1999, p.72). However, Cotsafis (2009, p.3) claims that "transforming a complicated ... system into a complex one is extremely beneficial for overall performance improvement", illustrating the notion with a metaphor of dogs driving a herd. Other authors (e.g. Bachelard, undated, cited in Schlindwein & Ison, 2004, p.29) see complexity not as a bad or good phenomenon, but as a fundamental issue of nature, for them there are no simple processes or concepts in the world, but only simplified ones.

2.4.3. Definition of complexity

Schlindwein & Ison (2004, p.28) state that there is no agreed definition of complexity in the literature and the existing definitions of the concept are very divergent (Cotsaftis, 2009, p.4). For example, there are many very context-specific definitions, which could not be directly transferred to other fields (e.g. project management). These include computational complexity, arithmetic hierarchy, entropy and self-organized systems (Cotsaftis, 2009, p.3) to name a few.

According to the definition of the Springer Complexity series "Complex Systems are systems that comprise many interacting parts with the ability to generate a new quality of macroscopic collective behaviour the manifestations of which are the spontaneous formation of distinctive temporal, spatial or functional structures." (Bertelle et al., 2009, front matter). However, the existence of many interacting parts can represent only one of the pre-requisites leading to new system behaviour, and thus should not be considered as a sole base for definition. Moreover, it does not explicitly relate the concept to the possibility to predict or explain the overall behaviour of the system, although it seems that this is implied by the "new quality of behaviour". For these reasons, the following definition proposed by Edmonds is considered more sound and relevant for the study.

> "Complexity is that property of a model which makes it difficult to formulate its overall behaviour in a given language, even when given reasonably complete information about its atomic components and their inter-relations" (Edmonds, 1999, p.72)

One of the important aspects of the definition is that it deals with the model of a complex system and not the system itself. This represents an advantage of the definition since it is almost impossible to identify system as a whole (especially a complex one), due to interrelations existing in the world (Edmonds, 1999, p.75). This also seems to be in line with the subjective dimension of complexity, since due to the existence of perception filters, the social actors deal with their perceptional models of the system (Vidal & Marle, 2008, p.1102).

2.5. Project complexity

2.5.1. Growing societal complexity and 'projectification'

In the light of the fast paced technological, social and economic change, complexity has become a ubiquitous term.

The past decades have been characterized by strong technological progress. The upheavals of innovations in the communication and transportation domain have made geographical distances insignificant and have brought the human interaction and information sharing to a whole new level, opening the way to globalization and internationalization. As the trade liberalization will continue to spread and national and global economies will continue to merge, the rate of change will accelerate even further (Jaafari, 2001, cited in Jaafari, 2003, p. 48). With the evolution of economies the inter-relationships and interactions are becoming more complicated leading to an increased societal complexity (Thomas & Mengel, 2008, p. 308).

Increased social complexity results in complex adaptive systems increasingly evolving throughout organizations (Rosenhead, 1998, cited in Thomas & Mengel, 2008, p. 308). As companies are running under the mantra of "faster, cheaper, quicker" (Cleland & Ireland, 2007, p.18), facing fierce competition, they are striving to come up with innovative products and to constantly upgrade their existing product lines with new features and to deliver them as fast as possible to the market (Williams, 1995, cited in Williams, 1999a, p. 272; Gray & Larson, 2008, p. 7). In addition to that, as companies are trying to meet best their customers' demands, the products and services provided have become highly customized (Maylor, 2001, p. 94; Gray & Larson, 2008, p. 11). All these reasons have led to an accentuated product complexity that entails complex production processes.

In order to meet these new demands and deliver competitive products, companies need a strong mix of resources, skills and competences, which often exceed their boundaries. Therefore there is an increasing number of partnerships between companies, working together to bring more sophisticated products and higher technology (Osterwalder & Pigneur, 2009, p. 39). On the other hand, in the pursuit of minimizing costs, companies are outsourcing less profitable operations. Thus, as the number of stakeholders has increased dramatically, companies are facing the challenge of managing wider and more diverse and dispersed teams, facing multiculturalism and conflicting interests.

As a response to these new challenges, companies have gradually moved from the traditional management to project management. Thus, although in the beginning it was practiced only in one-off activity industries, such as construction engineering, it became widely spread in all fields in the past years (Grabher, 2002, p. 206). As projects have become a core business process for most companies (Maylor, 2001, p. 92), they represent one of the four pillars on which modern organizations are standing (Van Der Merwe, 2002, p. 402). In companies with flatter hierarchical structures, project management has even replaced the middle management (Gray & Larson, 2008, p. 3).

Inevitably the "complexification" of the society and business environment was reflected in the organizational "projectification" process. According to Laufer et al. (1996, cited in Williams, 1999a, p. 272), projects' evolution was characterized by an increasing complexity: while four decades ago they were simple and certain, in the past 20 years projects have become complex, uncertain and quick. As there is an accentuated trend of project duration compression, fast delivery of projects has become an important success factor for winning bids (Williams, 1999a, p. 272). These tighter time constraints have led to "parallelism and concurrency, which by definition increases project complexity further" (ibid). Furthermore in the context of increased technical, social and economical complexity, project managers have to cope with a wider range of tasks, issues and problems (Tuman, 1986, cited in Williams, 1995, p. 19).

Thus, as complexity seems to have become a common attribute for the practice of project management, it inevitably appeared the need for an extensive knowledge on the topic. The high number of failures in projects, showed that traditional project management methods were no longer sufficient, being unable to contend with the increased contextual diversity (Baccarini 1996, p. 201; Maylor et al., 2008, p. S16). As complex projects require prodigious management skills and tools, it is important for practitioners to be able to assess the level of complexity they have to deal with, in order to adjust the resources and capabilities to the specific project needs (Shenhar, 2001). Furthermore, a two year study of a UK government-funded research network (Rethinking Project Management Network), that aimed to identify the gaps between the academic research in project management and the reality of its practice, in order to propose a number of future lines of research in project management, indicated the study of theories of the complexity of projects and project management to be the most stringent direction of research (Winter et al., 2006).

Due to aforementioned, according to Geraldi et al. (2011, p. 968), more and more researchers showed interest in the topic, exploring the concept of project complexity either from a practitioners' perspective (Jaafari, 2003; Williams, 2005; Geraldi & Adlbrecht, 2007; Maylor et al., 2008) or from a complexity theory perspective (Cicmil & Marshall, 2005; Cooke-Davies et al., 2007). In the context of a widespread projectification in all industries, the study of project complexity became an attractive topic, surpassing the boundaries of the project management field to areas such as: IT (Ribbers & Schoo, 2002; Xia & Lee, 2005) and construction (Cicmil & Marshall, 2005).

2.5.2. Definition of project complexity

While many studies were done, most researchers tried to depict project complexity by identifying its constituent elements, without actually providing a definition of the concept itself. However, in certain papers, several characteristics of the term were outlined, such as: difficulty (Wozniak, 1993, cited in Baccarini, 1996, p. 202) or something that produces "overall difficulties and messiness of the overall project" (Williams, 1999a, p. 271) and "something [...] that makes a project unique, more complicated, and more difficult to execute, manage and control" (Geraldi, 2009, p. 665).

Baccarini (1996), a promoter of descriptive complexity, defined project complexity as only "consisting of many varied interrelated parts" (p. 201), thus narrowing its understanding. However, Vidal & Marle (2008) proposed a comprehensive definition, based on Edmond's (1999) definition of complexity that was presented in the previous section and is supported in this research. Thus "project complexity is the property of a project which makes it difficult to understand, foresee and keep under control its overall behaviour, even when given reasonably complete information about the project system" Vidal & Marle, 2008, p. 1101).

Nonetheless, a significant contribution in understanding project complexity is brought by the study of its elements, that make projects difficult to manage and thus an extensive research was done to that effect. In the early papers researchers focused on a narrow set of elements (i.e. Baccarini, 1996; Shenhar & Dvir, 1996; Williams, 1999a; Jaafari, 2003; Xia & Lee, 2005). However, most of them suggested the investigation of further 'soft side' elements. As the research on the topic developed, the term of project complexity became more inclusive. In line with this expansionist evolution, the majority of articles published in the last five years adopted a holistic approach (i.e. Geraldi & Adlbrecht, 2007; Remington & Pollack, 2007; Maylor et al., 2008; Vidal & Marle 2008; Bosch-Rekveldt et al., 2011; Geraldi et al., 2011).

An overview of the elements identified by the researchers under the project complexity umbrella shows that there are lots of commonalities between the findings in the literature, although the studies were conducted independently, with no intention to build frameworks upon previous research. Thus, looking at the evolution of research on project complexity, it seems that the holistic studies confirmed the findings from the early literature. As more research was done on the comprehensive nature of complexity, the results overlapped even more. Such an example would be the MODeST framework developed by Maylor et al. (2008) and the TOE framework developed by Bosch-Rekveldt et al. (2011), which were developed independently from each other in about the same time frame, but had similar results, although the studies were done in different industries, using different approaches (Bosch-Rekveldt et al., 2011, p. 737). Furthermore, as Geraldi & Adlbrecht (2007, p. 34) point out, there is no ideal pattern of complexity due to its subjective side and thus it would be impossible for two different studies to identify the exact same elements of complexity.

2.5.3. Dimensions of project complexity

Despite the disagreement on the specific elements, researchers seem to have reached an agreement regarding the main streams of project complexity. In a recent review of articles published on project complexity, Geraldi et al. (2011, p. 972) made an interesting observation, emphasizing that no new types of complexity emerged in 2009 and 2010. Nonetheless, despite the conceptual agreement on project complexity, there is no common language. As it can be seen from Table 1, researchers use a very diverse vocabulary to label the types of complexity. Furthermore, very often same terminology is used in different articles to express different concepts, which creates confusion and ambiguity for the reader.

Table 1. Overview of project complexity elements

Complexity / Articles	Static dimension			Dynamic dimension
	Objective	Objective and Subjective	Subjective	
	Structural complexity	Uncertainty	Perceived complexity	
Baccarini (1996)	Complexity (number of elements, interdependency)	-	-	-
Shenhar & Dvir (1996)	System scope (size)	Technological uncertainty (new technology) *Also suggested the study of non-technological uncertainties stemming from project environment*	-	-
Williams (1999a)	Structural complexity (number of elements, interdependency) *Suggests: conflicting goals and multiplicity of stajeholders*	Uncertainty in methods (stochastic elements; lack of knowledge, lack of experience)	*Suggests study of "softer elements"*	Uncertainty in goals (change of users' requirements)
Ribbers & Schoo (2002)	Variety (number of elements and interrelations)	Integration (degree of innovation)	-	Variability (dynamics over time)
Jaafari (2003)	-	-	Project complexity (Stakeholders management – human and organizational factors) and Environmental complexity	-
Xia & Lee (2005)	Structural complexity (variety, multiplicity, differentiation; interdependency)	-	-	Dynamic complexity (changes in..)
Remington & Pollack (2007)	Structural complexity (size, interconnectedness)	Technical complexity (new situation,	Directional complexity (ambiguity of	Temporal complexity

		unknown or untried techniques)	goals and objectives)	
Geraldi & Adlbrecht (2007)	Complexity of fact (Number of elements, Interdependence) Complexity of interaction (Reference)	Complexity of faith (unique, new, high uncertainty)	Complexity of interaction (Empathy)	Complexity of faith (Dynamics)
Maylor et al. (2008)	Structural complexity (Mission, Organization, Delivery, Stakeholders, Team)	Structural complexity (Mission – Uncertainty)	Structural complexity (Mission, Organization, Delivery, Stakeholders, Team)	Dynamic dimension

From a temporal point of view, project complexity can by analyzed through a dual perspective: static and dynamic. Thus from the static perspective, one can assess project complexity at a certain point in time, having a snapshot view of its constituent elements and their interrelations, comprising organizational, technical and environmental aspects (Maylor et al., 2008, p. S18). On the other hand, from a dynamic perspective one can assess the variation of static complexity in time, looking at the variation of each constituent element of the analyzed snapshots.

Static complexity

According to the study of Maylor et al. (2008, p. S20), the elements of static complexity are "either an initial condition or an element with, at best, some temporary stability". Considering that the temporal aspect that leads to dynamic complexity comes into play only with the approval of the project and the beginning of its execution, the static complexity plays an important role in the planning phase of the project. That represents the initial time (T_0), where the complexity elements are in their "primal state".

For the purpose of this research, the elements of static complexity will be grouped considering their objective/subjective nature, in line with Casti's (1992) observation regarding the dual character of complexity. There were identified three main categories: structural complexity, uncertainty and perceived complexity.

Structural complexity

The structural complexity depicts the objective aspect of project complexity, falling under Schlindwein & Ison's (2004) category of descriptive complexity. Thus it delineates the intrinsic property of a system, illustrating the "big" (Williams, 1999a, p. 269) and "complicated" (Remington & Pollack, 2007, p.7) attributes of project complexity. Baccarini (1996, p. 201) synthesizes it as "consisting of many varied interrelated parts". In line with this definition, there are three attributes of structural complexity recurring in the literature: size (Shenhar & Dvir, 1996; Williams, 1999a;

Xia & Lee, 2005; Remington & Pollack, 2007; Geraldi & Adlbrecht, 2007; Vidal & Marle, 2008), variety (Williams, 1999a; Ribbers & Schoo, 2002; Xia & Lee, 2005; Vidal & Marle, 2008) and interdependence (Williams, 1999a; Xia & Lee, 2005; Remington & Pollack, 2007; Geraldi & Adlbrecht, 2007; Vidal & Marle, 2008).

Uncertainty

Uncertainty represents the gap between the information required to make a decision or to complete a task and the amount of information available (Galbraith, 1977, p. 5; Probst & Gomez, 1991, cited in Geraldi et al., 2011, pp. 977-978), thus underpinning the general lack of knowledge about a situation. Therefore uncertainty impairs the accurate prediction of future (Shenhar & Dvir, 1996, p. 610). Uncertainty can reside in both objective and subjective sources. The objective source is characterized by break-through novelty and uniqueness, which is usually, encountered in the development of new technologies and processes, where there is no point of referral, no existent source of information (Shenhar & Dvir, 1996; Remington & Pollack, 2007, p. 7). The subjective source is characterized by the novelty of the situation for the individual, thus being highly related with his previous experience and his ability to localize supporting information (Geraldi & Adlbrecht, 2007, p. 35). High uncertainty entails a wide variety of options and possible decisions, with too few information available to indicate an optimal solution (Remington & Pollack, 2007, p. 7; Geraldi & Adlbrecht, 2007, p. 35). Thus very often rework is expected as it's a learning by doing process.

Perceived complexity

The perceived complexity underpins the subjective aspect of project complexity as it relies on the observer's view of reality. According to Jaafari (2003, p. 49), individuals have their own perception of the surrounding environment, in consonance with their mental models. While "a certain amount of internalization of the outside reality or complexity reduction of the environment is needed" in order to grasp the complexities of the environment, it is possible for individuals to either over simplify or over complicate reality (Jaafari, 2003, p 49). Thus, the perceived complexity resides in the individual's capacity to understand it and to handle it, according to his experience and to his educational, financial and cultural background. Therefore it is often associated with the term of "difficulty" (Wozniak, 1993, cited in Baccarini, 1996, p. 202) as it depends on the subject's capabilities.

The most recurrent attribute that emerged in the literature is the ambiguity of vision and goals and fuzziness of meaning that lie in multiple interpretations of individuals (Remington & Pollack, 2007, p. 7). Furthermore Geraldi & Adlbrecht (2007, p. 35) emphasized as a part of complexity of interaction, individuals' ability to work in a certain team (stakeholders' empathy), which was also reinforced by the findings of Vidal et al. (2011, p. 725), who highlighted the importance of team cooperation and communication.

Dynamic complexity

Every single element of the static complexity can vary in time, throughout project life-cycle, affecting the level of interaction in the project and leading to dynamic complexity (Maylor et al., 2008, p. S20). However, while some elements are less prone to change through their relative stable nature, such as (budgetary) size of project or project uniqueness (Geraldi & Albrecht, 2007, p. 40), other elements have been shown to display high variability, such as project scope (Ribbers & Schoo, 2002, p. 46; Maylor et al. 2). According to Xia & Lee (2005, p. 55), changes occur as a consequence of the "stochastic nature of the environment" or due to high uncertainty, which translates into a lack of information regarding the project environment, leading to non-linear cause-effect relationships.

Thus the more unstable is the environment the higher is the probability of a more accentuated dynamic complexity. Furthermore, the interdependencies between the variability of different elements cause additional dynamic complexity. In such context, the traditional project management tools and methods proved have to be inefficient in dealing with fast paced change, which led to an increased emphasis on agile project management methods. In this new approach, the traditional practices of project planning from head to tail, followed by project implementation, have been replaced with a step by step technique, entailing a sequence of short planning and implementation cycles, allowing constant adaptation to the environment's new characteristics and constraints (Maylor et al., 2008, p. S24).

2.5.4. Project complexity measures

Certainly, the identification of the sources of complexity in projects represents an important step in understanding which elements will oppose higher difficulty and what are the potential risks. As the research evolved, authors tried to develop comprehensive frameworks aiming to "describe the managerial complexity in a manner consistent with the actuality of the lived project management environment" (Maylor et al., 2008, p. S15); "to support project managers to reflect pragmatically, but still "holistically," about complexity in projects and about how they could act in order to positively navigate complex situations" (Geraldi & Adlbrecht, 2007, p. 34). Thus the main practical implications of the project complexity frameworks is to gain a deeper understanding of the reality of projects and their environment, to challenge the existing paradigms (Maylor et al., 2008, p. S24) and to help project managers pursue an active management.

However, in order to be able to differentiate projects according to their level of complexity and to use project complexity as a criterion in the project prioritization and selection process, it is necessary to have a system of reference. Notwithstanding, while many researchers developed complexity frameworks to depict the elements of project complexity, only few of them proposed methods to quantify it.

The widest literature on project complexity parameters can be found in the area of descriptive complexity. The objective nature of the structural complexity and the countable nature of its attributes impinged researchers to develop a number of measures in order to quantify it. In the first publication explicitly focused on complexity in project management, Baccarini (1996) proposes a set of measures for the dimensions of complexity: number of varied elements (such as number of hierarchical levels, number of units/tasks, number of inputs/outputs, number of separate and different actions/tasks etc.) and degree of interdependency (between project organizational elements, tasks, inputs), which are highly quantifiable, and thus can easily be translated into parameters. Williams (1999a, p. 270) provided further examples of measures of interdependencies such as sequential complexity (the likely length of a sequence of interactions) and feedback complexity (the probability that a change in system i eventually affects system i). As the research on the topic developed, additional measures were inserted under the three main dimensions: size, variety and interdependency.

However, as far as uncertainty is concerned, as it underpins the missing amount of information that would have been necessary to perform a task or make a decision, it is by definition impossible to quantify, as one cannot measure what he or she doesn't know. Williams (1999a) himself, the first researcher to consider the concept of uncertainty as part of project complexity, recognized that the uncertainty categories he proposed are difficult to be operationalised into a quantifiable parameter.

With the introduction of perceived complexity elements, the assessment of project complexity became a subjective process by nature, as it is influenced by the mental model of the beholder (Jaafari, 2003, p. 49) and his previous experiences (Bosch-Rekveldt et al., 2011, p. 735). Therefore, different individuals can have different perceptions on what is complex and to what extent something is complex. Furthermore, individuals perceive only a part of the complexity characteristics, first due to the non-analyzable nature of "ontological complexity" and second due to the time constraints that impede them to perform deep reflections on the matter of project complexity (Geraldi & Adlbrecht, 2007, p. 33). Thus, the majority of the researchers that proposed a holistic approach to project complexity aimed solely a deeper understanding of the concept, without trying to model it. Geraldi et al. (2011, p. 982) suggested that project complexity should be studied through perceptual means, given its subjective nature.

Vidal et al. (2011) did a recent literature review on project complexity parameters that was based mainly on the papers of Edmods (1999), Latva-Koivisto (2001) and Nassar & Hegab (2006). They compiled a list of 42 complexity parameters and grouped them into three main categories: computational complexity parameters, project network parameters and holistic parameters. However, as supporters of the holistic view of project complexity they found the first category not to reflect the quintessence of the concept and the second category to be too narrow and also unreliable. As far as the existing holistic complexity measures were concerned, they argued that they were difficult to compute and thus impractical. In order to overcome these limitations they identified the most relevant complexity factors using systems thinking and then proposed a complexity index based on the analytic hierarchy process (AHP).

2.5.5. Project network complexity

This subsection discusses approaches to define project complexity parameters, on the basis of project network representation. Although these do not represent the focus of the study, the authors believe that without thorough discussion of this approach, as well as without its strong points and limitations, the literature review would not be complete. This is because the approach is a logical extension of the mentioned Operations Research stream to the field of the project complexity and we followed a balanced approach in the literature review. The subsection encompasses explanation of the major Operations Research models of projects, introduction of corresponding complexity measures and discussion of limitations and possible value of the models and parameters.

Project models as a simplification of reality

Any model represents a simplification of the reality (Jaafari, 2003, p.49), aimed to reflect (and help to comprehend) dependences among the parts or elements of the whole, which are deemed to be critical. For instance, project models have been based for a long time on notions of planning and control regarding traditional objectives of time, cost and scope (Vidal & Marle, 2008, p.1095). The development of traditional models enhanced existing PM practice and understanding of 'hard' side of projects. However, modelling is an intricate process, especially in social sciences, where the influencing factors are often difficult to operationalise. In addition, it does not reflect subjective perceptions of the project by social actors and cannot accommodate cultural and social backgrounds.

Apparent advantage of the use of models lies in opportunity to apply powerful tools based on mathematical analysis, statistics, probability theory, graphs theory, applied and computational mathematics. The application of the approaches initially developed for natural sciences problems has resulted in advancements in different fields of project management (Tavares, 2002, p.2), most notably in scheduling and risk management (Williams, 1995, p.26). An important feature of the results obtained via the analysis is that they are theoretically applicable to a very broad range of cases as long as (and as far as) model's assumption about real life holds true.

The main disadvantage of the modelling is that project models (at least currently existing) simplify the reality; as some authors insist, too much (Jaafari, 2003, p.53). Moreover, since a project model can be considered as the first layer of project perception (Vidal & Marle, 2008, p.1096), simplified models themselves may represent limitations for both practice and theory. Overall, we think that although models represent useful means to study projects, their limitations should be taken into consideration during all research phases, including research design and analysis of the results.

Basic project model

Notion of directed acyclic graph

Battersby (1967, cited in Tavares, 2002, p.2) developed a basic model to represent projects – directed and acyclic graph (DAG, Fig. 1), which has formed the basis for the project modelling. Following this, each project, according to Tavares (2002, p.2), can be described by the following elements:

a) A discrete and finite set of entities (activities) A, $A = \{A_i: i = 1, \dots, N\}$, where N is the number of the project activities
b) A set of precedence conditions J, $J = \{J_i: i = 1, \dots, N\}$, where J_i is a set of activities immediately preceding i. Similarly, the set of activities which are the immediate successors of i, K_i, can be defined by $K_i\{k: i \in J_k\}$
c) A discrete and finite set of attributes for each activity i, $\{B_1(i), \dots, B_p(i)\}$ with $p \geq 1$ and describing the activity properties, such as cost, duration, resources required etc.
d) A discrete and finite set of criteria $\{V_1, \dots, V_q\}$, expressing values according to which decisions regarding project should be made by the manager (i.e. total project duration, cost, NPV etc.).

According to this widely adopted though basic model, the set of activities is pre-defined and an activity starts when all its direct precedents are completed, which is a simplification of the real project. One of the properties of DAG is that it is impossible to start at node i and after following certain subset of precedence relations arrive to the same node i. In practice that means that reworks are not accommodated in the model. The property has been criticised and an attempt was made to apply Markov process in order to deal with the limitation (Hardie, 2001). The model is also scant in terms of activity descriptions, since it allows only invariable numbers attached to individual activities. The advancements of the basic model developed in the literature typically follow improvements along four dimensions defined above (a-d).

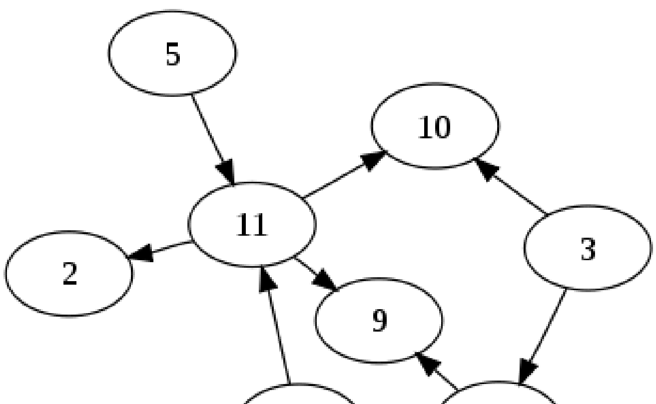

Figure 1. An Example of Directed Acyclic Graph (DAG). Source: Wikipedia

Main graphical representations (project networks)

There are two major conventions – “Activity on Arc” (AoA), where activities are shown on arcs of graph and nodes represents junctions of several activities and “Activity on Nodes” (AoN), where activities are represented on nodes and arcs show precedence relationships. The AoA notation is more widespread because of the relation to the popular CPM/PERT methods (Tavares, 2002, p.3), whereas AoN is used as a foundation for the development of stochastic activity networks (Shih, 2005, p.745).

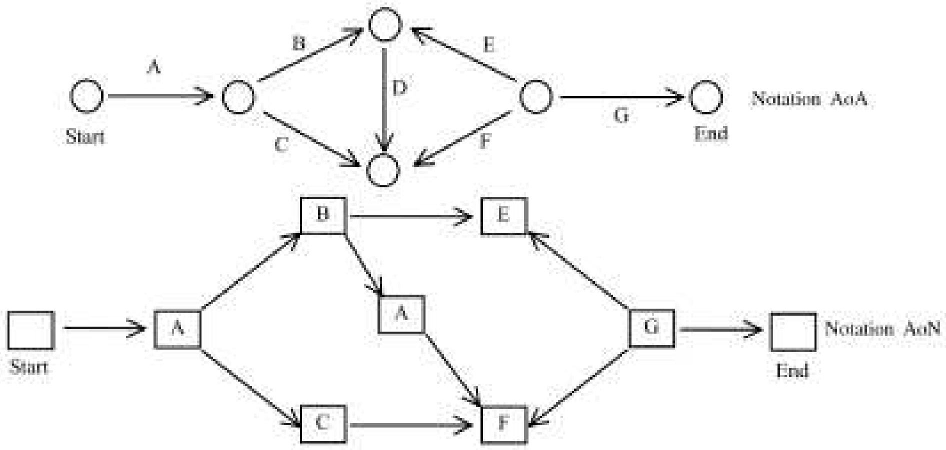

Figure 2. Examples of AoA and AoN representations. Source: Tavares (2002, p.3)

Further developments of the project model

A number of project models were suggested to overcome inherent limitations of the acyclic directed graph representation. These include development of generalized ‘probabilistic networks’ (Kauffmann & Desbazeille, 1964, cited in Tavares, 2002, p. 3) in which certain activities may occur with a pre-defined probability, ‘logical networks’ (Battersby, 1967, cited ibid, p. 3) in which occurrence of upcoming activities is logically dependent on occurrence and characteristics of completed activities, modelling of activities overlapping in time (Leashman & Kun, 1993, cited ibid, p. 3) (e.g. considered in details in the ‘Precedence Diagramming Method’) and ‘hammock activities’ (Harhalakis, 1990, cited ibid, p. 3), that are ‘filling’ activities between two events occurring during other activities. Another line of inquiry is the study of hierarchical networks both in terms of project decomposition in sub-tasks of different levels and in terms of aggregation of lower level activities in less complicated networks (Speranza & Vercellis, 1993; Muller & Spinrad, 1989, cited in Tavares, 2002, p.4). Recently, project modelling has been approached from the system dynamics perspective in order to overcome the assumption of passive management implied in the network models (Williams, 1999b).

Although the described models represent reality better, they are much more complicated for the analysis and arguably less understood and used by practitioners. This can be illustrated by the notion that although some of the approaches exist for more than 40 years they have not become common practice (for example, they are typically not included in project management software).

Stochastic Activity Networks

The basic model of project leads to a popular Critical Path Method (CPM), the simplicity of which has an important drawback that is inability to accommodate stochastic nature of the project activity attributes, e.g. time and cost.

Definition of a stochastic activity network includes a)-c) elements of the basic model definition with one notable exception, that is the set of attributes $\{B_1(i), \ldots, B_p(i)\}$ for activity i represent the probability distribution of the attribute (given as a discrete probability distribution or a probability density function for continuous variables).

Although the SAN network is seemingly more realistic project model, one of its limitations is related to the quality of input data. The problem is that the real probability density functions of activities attributes (e.g. activities) are not known and even the form of the distribution function is still debatable, after many years of scientific publications on the issue (Williams, 1995, p.27; Shih, 2005, p.744). The SAN also inherits other issues associated with the DAG model, e.g. that is impossible to start next activity before finishing the precedent activity and reworks are not accommodated within the model.

Overview of different network complexity measures in the literature

Project network complexity parameters represent a subset of structural complexity category proposed by Baccarini (1996). Several authors actively contributed to the development of complexity measures of networks/schedules, most notably Kaimann (1974), Elmaghraby & Herroelen (1980), Tavares et al. (1999, 2004), Nassar & Hegab (2006), Vanhoucke et al. (2008). The systems of parameters suggested by the authors are outlines below. This is followed by the discussion on their comparison, advantages and disadvantages.

<u>Kaimann (1974)</u>

Following the AoA notation, the coefficient of network complexity is defined as (Kaimann, 1974, p.173):

$$CNC = \frac{(Number\ of\ activities)^2}{Number\ of\ nodes/junctures}$$

The coefficient aims to measure interconnectivity of a network as an indication of its complexity. The important advantage of the parameter is its simplicity. The author also discusses potential applications of the parameter to project classification and planning (p.176). The CNC factor defined above was criticized on the grounds that it depends only on numbers of activities and nodes, hence failing to discriminate between networks having the same number of nodes and activities, but at the same time exhibiting different morphological complexities (Elmaghraby & Herroelen, 1980, p.223).

Elmaghraby & Herroelen (1980)

The authors suggested that complexity parameters should reflect difficulty in analysis and synthesis of a network and thus argued that the actual complexity parameters developed should be contingent on particular objective adopted, for example whether it is applied to deterministic, stochastic or resource-constrained problem (Elmaghraby & Herroelen, 1980, p. 223). For the first two objectives the AoA notation was adopted.

For deterministic problem, the authors suggested that the network complexity parameter should reflect the computational time, required to numerically identify the critical path. Thus the two parameters driving computational complexity were suggested:

(1) A-a1, where A is a number of activities and a1 – the number of arcs out of node 1;

(2) A-N+1, where N – number of nodes.

The rationale behind the parameters is related to the number of operations required to perform 'additions' of durations for sequential parts of network (parameter 1) and 'comparisons' for parallel parts (parameter 2).

The major limitation of the approach is that it reflects solely computational complexity, which may not correlate with other forms of complexity (e.g. regarding pronounced predictability of behaviour). Moreover, the final form of the complexity parameter, as a function of number of activities and nodes, depends on the quality of the computer hardware and even "the programmer's skill" (implies the computational algorithm adopted) (Elmaghraby & Herroelen, 1980, p. 228).

Similar logic based on computational effort requirement was applied for the second case, regarding stochastic networks. Here the three parameters suggested were numbers of (1) multiplications, (2) convolutions and (3) integrations required to obtain probability density function of the completion time. Since these parameters, depend on particular algorithm applied, similarly to the previous case, they do not seem to characterise the networks themselves.

Tavares et al. (1999)

One of the most important works in the field belongs to Tavares et al. (1999), where they proposed six morphological factors describing complexity of project networks. The parameters suggested by the authors use the concept of network hierarchical ranks defined as follows (AoN notation is used):

Def. Progressive level: $a_i = \max_{j \in J(i)} a_j + 1$. The maximal progressive level is denoted *M*. If there is no direct precedent activities for the activity i, $a_i=1$ by definition.

Regressive level: $b_i = \min_{k \in K(i)} b_k - 1$. When *K(i)* is empty, then $b_i=M$.

Level float: $\Delta_i = b_i - a_i$

Level length of a precedence link: $L(i,k) = a(k) - a(i)$

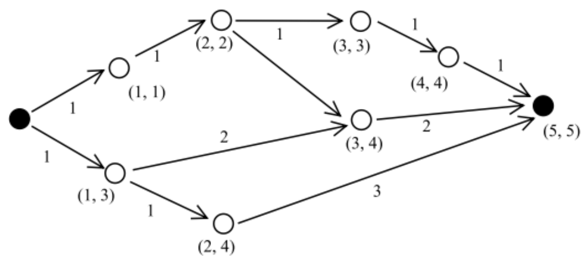

Figure 3. The progressive and regressive order of the activities of a network (an example). Source: Tavares (2002, p.4)

The six parameters are defined as follows:

1) $I_1 = N, where\ N\ is\ a\ number\ of\ activities$, representing size of network
2) $I_2 = \frac{M-1}{N-1}, where\ M\ is\ the\ maximum\ progressive\ level$, representing how serial the network in question is (0 and 1 correspond to parallel and serial case respectively).
3) $I_3(a) = W(a) - \frac{1}{N} - M, where\ W(a)$ is a number of activities at each progressive level, representing the network's 'width'
4) $I_4 = \frac{n(l)-N}{D-N}, where\ D\ is\ given\ by\ W(1) + \sum_{a=1}^{M} W(a) \cdot W(a+1)$, representing interconnectivity of the network
5) $I_5 = p = \frac{n(L+1)}{n(L)}, with\ L = 1,2, \dots V, where\ V\ is\ the\ maximal\ length$. Additional assumption is made here that p is constant for any L. The parameter represent
6) $I_6 = \frac{V-1}{M-1}$, representing relative length of direct precedence link in comparison with the maximum progressive level.

The parameters described created foundation for the subsequent studies of morphological features of networks. The latest version of parameters was developed by Vanhoucke et al. (2008), where I_3 and I_5 undergone minor modifications and I_6 was replaced by a new indicator representing topological float.

Discussion

Value of using the network complexity parameters

The important question is what the network complexity parameters can indicate and what is the value in using them. The answer to the question is three-fold. Firstly, the complexity parameters may serve as predictors of the project's behaviour (Nassar, 2010, p.8; Tavares, 1999, p.537). Secondly, they may also help to indicate the projects or specific activities, which require higher degree of attention from the management to plan and control them (Kaimann, 1974, p.176; Williams, 1995, p.26). Finally, the complexity measures albeit purely quantitative may nevertheless reflect other dimensions of complexity. For instance, if a project schedule is 'complex' in terms of a number of parallel activities which are required to be executed simultaneously, then it could be an indication of higher level of communication required to ensure a fit among the activities. Some additional benefits can be associated with more narrow definitions of complexity, for example computational efforts required to assist decision-making in terms of resource scheduling.

Limitations

All the project models described above and consequently the network complexity measures associated with them are subject to a number of important limitations. For instance, although a set of project activities are subject to dynamic nature of external environment, the occurrence of reworks or additional works is not considered in the models (Hardie, 2001, p. 402; Tavares, 2002, p. 5). Further, correlation between activities is not taken into account (Hardie, 2001, p. 401), which can be both positive, for example if some activities are delayed it could mean that our assumption on resources productivity was wrong and consequently all similar activities are likely to be delayed, or negative, when efficient management response ensures on-time delivery due to fixing the reason causing delay (Williams, 1999b, p. 308).

Another problem associated with the models is related to the belief that all relevant inputs of the models can be objectively and explicitly identified, often in the form of mathematical functions. However, this is often not the case, as any data elicitation has to deal with the perception problem and subjective dimension of social systems (Jaafari, 2003). Finally, the choice of categories to describe projects with a finite set of characteristics is subjective in its nature and it is an open question whether the representation of a project with a finite set of parameters is still valid given the increasing complexity.

2.6. Relationship between complexity, uncertainty and risk

There has been a lot of debate in the literature regarding the nature of relationships in the uncertainty-complexity-risk triangle. In every single aspect, researchers seem to have contradictory views. However, in some cases the disagreement does not stem from the relationship between any of these two concepts but from their different understanding of the concepts themselves, as it will be illustrated in several examples below.

2.6.1. Uncertainty vs. Risk

The PMBOK (2000, p. 127), defined project risk as "an uncertain event or condition that, if it occurs, has a positive or negative effect on a project objective". Thus traditionally risk and uncertainty were perceived as equal terms. However, Perminova et al. (2008), introduced a new view upon the link between the two concepts, proposing a cause-effect relationship between uncertainty and risk, defining the uncertainty as a "context for risks as events", emphasizing the dual nature of its outcomes, which can be either positive or negative.

This paper supports the idea of uncertainty representing a source of risk, in line with the view of Perminova et al. (2008). Considering that uncertainty is understood as the lack of knowledge surrounding the project environment, it represents a very broad concept. Therefore, it would not be sound to state that every missing piece of information can lead to a possible event that actually has an impact on project's objectives.

2.6.2. Complexity vs. Uncertainty

Some of the early articles that discussed the relationship between complexity and uncertainty considered them to be two different concepts (Bennett, 1991, Miller, 1973, Mintzberg, 1991, cited in Baccarini, 1996, p. 202). However, at that time, the research on project complexity was in its incipient stage and thus it had the narrow understanding, being the equivalent of what researchers label today as structural complexity, which is indeed a different concept than uncertainty. As it was mentioned above, with the development of the research on project complexity, the term became more comprehensive, gathering as well the concepts of uncertainty and perceived complexity under its umbrella (Williams, 1999a; Bosch-Rekveldt et al., 2011). Nonetheless, there are several authors that do not consider uncertainty as a source of project complexity. Vidal & Marle (2008) state that uncertainty is a consequence of project complexity, arguing that project complexity, through its "high number and variety of elements and interactions that cannot be completely neither identified nor understood" hinder project managers' from making accurate forecasts.

According to the PMBOK (2000, p. 4), "a project is a temporary endeavour, to create a unique product or service". As projects entail by definition the element of novelty, there is inevitably a gap of information and knowledge, between the available information and the required information to fulfil a task, which means that uncertainty is an inherent characteristic of projects. The higher is the level of novelty, the higher is the gap of knowledge and the less obvious is the optimal solution, becoming just another alternative in the multitude of options. Thus the project becomes a complex and more difficult to manage, the changes of taking wrong decisions increasing dramatically. Therefore our conclusion is that the inherent uncertainty of projects in itself is a source of complexity, representing the main driving force that makes complex system behave in an unpredictable manner. One of the implications of this relationship is the dual connotation of complexity, positive and negative. As uncertainty can have both positive and negative impact on projects' outcomes (Perminova et al., 2008, p. 76), and uncertainty is a source of complexity, it results that complexity can bring both challenges and opportunities.

2.6.3. Complexity vs. Risk

As far as the relationship between complexity and risk is concerned it appears that most of researchers agree upon the fact that complexity is a factor of project risk (Xia & Lee, 2005; Vidal & Marle, 2008). On the other hand, Bosch-Rekveldt et al. (2011, p. 731) propose a circular relationship between the two concepts, stating that in addition to the classic view, of complexity being a trigger for projects risk, complexity can be also be induced by a number of risks. Thus, they introduce a risk element under every category of their TOE framework for characterizing project complexity, arguing that, for example, riskier projects have a higher level of interaction and dynamics.

We argue that complexity delineates a property of projects that causes an unpredictable and difficult to control behaviour, increasing the probability of risk occurrence. Therefore, complexity implies a state of uncertainty which may give rise to one or more risks, which can lead to losses or positive outcomes.

This relationship has a very important practical implication, suggesting that complexity assessment can be used as an aid in project risk management (Vidal & Marle, 2008). By evaluating the level of project complexity, one can not only identify the risks triggered by it but also understand their likelihood. Furthermore, as the complexity assessment is looking at the current characteristics of the projects, it is more tangible and can be done more accurately than the risk assessment, which entails making assumptions about the future (Geraldi, 2009). Thus the complexity assessment has the advantage of guiding project managers in actively shaping the current characteristics of the project in order to prevent or mitigate future risks.

2.7. Impact of complexity on project performance

While in theory projects seemed to be the response to the changes in the environment, representing powerful tools to achieve specific objectives within defined constraints of time, cost and quality (Van der Merwe, 2002), in practice they showed to be a challenging endeavour, often failing to meet their goals. Thus, the past decades of project management have been characterized by project delays and budget overruns and with the evolution of projects throughout time towards complicated and uncertain undertakings, widespread across industries, the number of failures had increased considerably.

Williams (1995) illustrates this omnipresent nature of project failure throughout history as he reviews various recordings of project overruns. With the evolution of projects the number of delays has also increased. Williams (1995) does a review of historical evidences of project failures. In 1987, Morris and Hough, developed a list of 33 references containing databases of project out-turns, which showed that overruns were rather the norm, only a few reports displaying a limited number of underruns. One example would be the World Bank Tenth Annual review of project performance audit results (1984) showed a gradual decline in performance, with an average time-overrun of 61%. Furthermore, in the analysis of the Pioneer Plant Study database it was shown delays of 0-30 months (Myers & Devey, 1984, cited in Williams, 1995, p. 22). In the Downey Report of the UK Ministry of Technology (1969) it was mentioned a previous study of the Ministry of Supply on roughly100 projects, performed in 1958, where it was recorded an average of 36% delays. Moreover, Artidi et al. (1985) describes a database of Turkish projects with time-overruns of 34%-44% (cited in Williams, 1995, p. 23).

A more recent survey on the project performance in the previous three years in the construction industry, taken between December 2007 and January 2008, by the Chartered Institute of Building, revealed that: 29% of 2000 low-rise building projects had delay, 67% of high-rise (more complex) building projects were delayed (with an astonishing rate of 18% having a delay longer than 6 months). Out of 122 engineering projects, 42% were delayed and again it was revealed that the best performers in terms of time compliance were the simpler or repetitive projects such as roads, water storage etc.

These later findings that show higher delays in more complex projects has been supported by previous findings in the literature that connect project complexity elements with time overruns. Fraser (1984, cited in Williams, 1995, p. 20) acknowledges that major projects need careful risk management, distinguishing between normal projects and large projects. In normal projects risks are easy to identify, the proportion between the individual risks and the size of the parties involved is relatively small, there are no extreme risks, there are difficulties in applying project risk management procedures However, all these characteristics do not apply to large projects; "in general beyond a certain size the risks of projects increase exponentially and this can either be appreciated at the beginning or discovered at the end" (Fraser, 1984, cited ibid). In the literature on complexity, the size of the project, in its different aspects (capital invested, number of activities, number of stakeholders, number of tools and methods used), has emerged as one recurring elements that contribute to project complexity (Shenhar & Dvir, 1996; Williams, 1999a; Xia & Lee, 2005; Remington & Pollack, 2007; Geraldi & Adlbrecht, 2007; Vidal & Marle, 2008).

The number and type of interdependencies between the project elements has even a greater impact on project performance. According to Williams (1999a, p. 270), reciprocal interdependencies bring a significant contribution to project complexity leading to reworks and feedback effects that translate into delays as the project deviates from the initial schedule and adopts an unpredicted behaviour. He emphasizes the limitation of the traditional techniques, which can support a large number of elements, but are unable to capture the complex intricacies between them, being one-dimensional – WBS has a hierarchical structure; project network diagrams have a sequential structure etc. (Williams, 2005, p. 502).

Thus it can be concluded that structural complexity it is a trigger of project delay through its constituent elements, size and interdependencies as project managers have difficulties in managing large and complicated projects. Furthermore, uncertainty is by definition impeding project managers in making accurate forecasts and thus underestimating project completion dates. However, most often these elements of project complexity do not occur in isolation. Often unpredictable events have a strong effect in structurally complex projects, perturbing the environment and leading to a precipitation of actions and decisions under pressure that eventually leads to catastrophic delays (Williams, 2005, p. 502).

Nonetheless, while the relationship between project complexity and project performance has been acknowledged in the literature (Rowlinson, 1988; Williams, 1999b, 2005; Vidal & Marle, 2008; Bosch-Rekveldt et al. 2011), there seem to be a shortage of empirical studies to strengthen the link between project delay and project complexity. Moreover, the existing studies did not cover the whole range of complexity dimensions and factors and tend to concentrated on a complicatedness' factors (such as project size).

2.8. Project completion date estimation

2.8.1. Context

In order to determine project delay it is first necessary to define a point of reference (planned completion date), according to which the delay can be measured. This reflects a strong linkage between concepts of planning or scheduling and project timeliness tracking. Consequently, a delay identified will also depend on the approach adopted to predict the project completion date. The following subsections discuss in more details the existing approaches for the completion date estimation.

At the same time it should be stated, that the problem of project completion date estimation is far from being clear and resolved in the literature. One of the major reasons for this is that the problem is closely related to other aspects of project management. For example, it is linked to the resources availability and therefore can be considered as one of the dimensions of constrained resources scheduling problem (Tavares, 2002, pp. 7-11). Moreover, time is dependent on the decisions made regarding costs and scope, as illustrated by the classical project objectives' triangle. Further, it is almost always based on the network models (Williams, 1999b, p. 305), whose limitations were discussed in the previous section of the literature review, such as the overlooking of the effect of managerial response actions on the completion date. Finally, it was found that due to the 'Parkinson's effect' actual completion date depends on the target date set, due to psychological reasons (Williams, 1999b, p. 308).

2.8.2. Critical review of the existing approaches

There has been a lot of scientific research devoted to the field, which resulted in a number of approaches to the problem (Elmaghraby, 2000; Yao & Chu, 2007; Adlakha, 1989). Nevertheless, according to Morris & Hough (1987) study mentioned above, the project time overruns are as high as 61% on average and "there are hardly any reports showing underruns…". The fact that the deadlines for the projects are often established according to the traditional approaches such as Critical Path Method (CPM) or Program Evaluation and Review Technique (PERT), can be an indicator that existing methods do not provide required accuracy for project completion date estimation. For instance, the PERT approach predicts (after a number of simplifying assumptions and application of the Central Limit Theorem) that project completion date should be normally distributed around the most probable value. This contradicts the empirical evidence (Williams, 1999b, p. 308) outlined above: in this case under-runs should have the same probability as over-runs and so would be encountered approximately with the same frequency. Probably a more realistic probability density function (p.d.f.) for the project completion date was suggested by Dodin & Sirvanci (1990), who claimed that the p.d.f. could take different forms from normal distribution to the extreme value distribution.

In the CPM approach activity durations are considered pre-defined and known in advance. In this case total project duration is provided by point estimate and thus it does not address the stochastic and random nature of schedule, receiving much criticism in the literature for its lack of uncertainty considerations (Lee, 2005; Lu & AbouRizk, 2000). The latter also criticize the rigidity of the method as it does not allow practitioners to incorporate their expertise into the decision making process.

There are four main classes of approaches to the estimation of project completion date probability density distribution (Yao & Chu, 2007, p.283): (1) exact analysis, (2) analytical bounding, (3) analytical approximation and (4) Monte-Carlo simulation.

Exact approaches as it follows from their name are aimed to obtain exact p.d.f. of the completion date. When such solution is possible, it represents the best case as it allows getting precise 'answer'. The main problem is that cases when exact solution is possible are scarce and usually require small and very specific network diagram and individual activity p.d.f. to be implemented. Consequently the approaches do not have practical significance (Yao & Chu, 2007, p. 283) existing mainly in the literature in the form of theorems in mathematical and operations research journals.

Analytical bounding is a method of obtaining lower and upper bounds for the project completion date p.d.f. (e.g. Kamburowski, 1986, cited in Williams, 1995, p. 26) Although useful for quick assessment of the extreme cases, the approach is also sensitive to the activity duration p.d.f. used and often provides quite wide estimates which cannot be used in practice. Hence, it is not surprising that for analytical bounding methods the researchers often do not provide any discussion of the results applicability to the real-life cases.

Probably one of the most important analytical approximation methods is PERT. The method has been actively critiqued in recent years (Lu & AbouRizk, 2000; Lee, 2005), but at the same time it is still actively used and included in the majority of PM software (e.g. MS Project). The reason for this is the method's simplicity. The main disadvantages of PERT are overlooking of secondary paths near the critical path, especially if they are characterized by large standard deviations, and making the assumption that activities are identically distributed, independent etc. Another branch of approximation methods are related to the discretization of the activities' p.d.f. and obtaining completion date p.d.f. using simplified computational algorithms (Yao & Chu, 2007, p. 284).

Finally, Monte-Carlo simulation is a powerful tool for project completion date estimation, as it allows obtaining 'close to exact' probability distribution of the completion date given individual activity distributions. There are several disadvantages of the approach though: Firstly, it requires heavy computational capacity making it impossible to apply directly to the large projects with a lot of activities, at least in managerial practice. Secondly, it requires preliminary information on the project network as well as distributions of all individual activities to be available and valid and 'quality' of the input data determines quality of the output distribution. This represents one of the method limitations as well as suggests that the relevance of the activity duration p.d.f. is of considerable importance. The following subsection discusses different p.d.f. used in the literature in more details.

2.8.3. Probability density functions

There is a lot of discussion concerning p.d.f. of project activities in the literature. Almost every major class of p.d.f. (including normal, lognormal, triangular, beta, gamma, Berny, Weibull, exponential and right truncated exponential, extreme value to name a few) is said to be most applicable to some particular cases (Berny, 1989; Bendell et al., 1995; Golenko-Ginzburg, 1988, etc.), although Fente et al. (2000) argues that several studies show that assigning an inappropriate activity p.d.f. does not lead to a significant error as there was no statistically significant difference in the output estimates (Wilson et al., 1982, Klein & Baris 1990, Touran 1997, Maio, 1998, cited in Fente et al., 2000, p. 234). The p.d.f. should reflect actual properties of activity times, e.g. unimodality (Swanson & Pazer, 1971), positive skewness (Golenko-Ginzburg, 1988), left truncation at the deadline duration (Tavares, 1986).

2.9. ERP system implementation projects

2.9.1. Peculiarities of ERP system implementation projects

The ERP system is an abbreviation standing for Enterprise Resource Planning system. According to Baraldi's definition, ERP system is "a particular type of IT system covering most information-rich tasks in an organisation: order management, production and material planning, inventory control, budgeting, HR management, accounting, customer data management etc" (Baraldi et al., 2009, pp. 24-25). From a technical perspective, the systems consist of a number of different databases, containing all relevant data, a set of software applications to process the data and a graphic user interface to simplify user interaction with the systems (ibid).

Consequently, such systems possess several important properties, such as a great degree of variety and interconnectedness between system elements (e.g. enquires to both production and accounting&finance databases are required to determine costs) and the ability to incorporate great variety of business models and operations existing in real business world. Furthermore, they are highly important, since nearly all operations are planned, processed and recorded with their aid. Thus ERP system represents to a certain extent a model of organization.

These peculiarities have a number of implications on the ERP system implementation projects. Firstly, the projects are associated with high stakes not only because they are quite protracted and expensive (Baraldi, 2009, p. 25), but also because successful implementation of ERP system leads to realization of significant benefits and "ERP adoption helps firms gain a competitive advantage over non-adopters" (Basoglu et al., 2007, p. 79). Even more importantly, the ERP system implementation always represents a major organizational change initiative (Markus & Tanis, 2000, cited in Kerimoglu et al., 2008, p. 23; Soja, 2008a, p. 106; Basoglu et al., 2007, p. 74). This is reflected in the fact that ERP system implementation is closely associated with Business Processes Reengineering (Kerimoglu et al., 2008, p. 26; Basoglu et al., 2007, p. 81), often requires profound changes in the way people work and occasionally leads to downsizing as a consequence of automation. Finally, the projects affect all functions existing in the organization (Kerimoglu et al., 2008, p. 26), and thus require efficient communication to ensure smooth integration of the system modules.

2.9.2. Success rate of ERP system implementation projects

Despite of the great expectation that business management often have from these projects, the success rate is quite low (Venugopal, 2005, p. 48; Sanchez et al., 2010, p. 87) and according to Basoglu et al. (2007, p. 79) "most of ERP projects become over-budget, late and even fail". Strikingly, up to three quarters of the ERP implementation projects are unsuccessful, being on average 178% over budget, taking 2.5 times longer than expected and realizing as low as 30% of promised benefit (Zhang, Lee, Huang, Zhang, & Huang, 2005 cited in Basoglu et al., 2007, p. 74).

Despite the fact that ERP systems nowadays have become widespread and the performance of implementation projects is far from ideal, academic research in the area is relatively new and scarce (Basoglu et al., 2007, p. 79). The existing research literature on ERP systems can be divided into three major strands that are: user adoption of ERP systems, case based studies and cultural issues in ERP use (ibid, p. 78).

2.9.3. Complexity of ERP system implementation projects

The scarcity of academic research in the domain especially holds true for the topic of project complexity. Although researchers often mention the term 'complexity' in regards to ERP system implementation projects (Soja, 2008a, p. 106; Baraldi, 2009, p. 19; Basoglu et al., 2007, p. 88; Kerimoglu et al., 2008, p. 23), and seem to agree that the ERP system implementation projects are the most complex among IT projects (Basoglu et al., 2007, p. 88; Kumar et al., 2003, Wilder & Davis, 1998, cited in Basoglu et al., 2007, p. 74), their approach often lacks holistic consideration of diverse complexity dimensions, which have been developed only recently (Geraldi et al., 2011). Specifically, complexity is considered predominantly from the technological perspective, i.e. technical features of ERP system as a complex product (Hobday, 1998, p. 691), reflecting supply-side point of view, e.g. provider's capabilities to design and implement the system (Baraldi, 2009, p. 20).

2.9.4. Reasons for ERP system implementation project failures

Given the poor project performance mentioned before, it is not surprising that the reasons for project failures and success factors are among the most popular research strands (Basoglu et al., 2007, pp. 79-80; Baraldi, 2009, p. 26; Soja, 2008a, p. 107). In the subsequent discussion the authors follow an excellent literature review of Basoglu et al. (2007), which focuses on reasons for project failures, including time overruns. Overall, researchers have approached the problem from different angles. Davenport (1998) suggested two basic reasons, the technical complexity and the misfit between business requirements and the system functionality. Buckhout et al. (1999) argued that the problems with the projects are mainly associated with inappropriate strategic decisions, e.g. on processes reengineering, and losing control over the implementation. In addition, the 'invisibility' of ERP system and lack of investment evaluation regarding the implementation project represent important factors (Umble et al., 2003, Griffith et al., 1999 cited in Basoglu et al., 2007, p. 79). Another important reason for failure is overlooking the people dimension (Basoglu et al., 2007, p. 79).

In addition, the studies on critical success factors are also relevant for the failure factors identification (Basoglu et al., 2007, p. 79), since the failure emerge when the conditions are not satisfied. Thus the factors mentioned above can be complemented with the following: lack of top management support and user acceptance; inappropriate or insufficient user training, project communication, project management, integration of systems, customization of ERP, process reengineering activities and ERP package selection; neglect of cultural differences and legacy systems. Further, Sanchez et al. (2010) accomplished empirical study distinguishing between 'value-chain' and 'business support' ERP modules in terms of implementation durations, and stating that this difference is due to different levels of interconnectedness.

Apart from the studies on ERP implementation projects, many studies were done on reasons for failure of more general IT-projects. For instance, in Wilder & Davis (1998, cited in Basoglu et al., 2007, p. 74) study poor planning and management, change in business goals during the implementation and lack of client management support were regarded as the most important reasons for failures. However, typically researchers consider generic project failure, and the studies focusing on specific dimensions (i.e. time and cost overruns, user satisfaction etc.) are by far less common.

To the best of our knowledge there is only one work specifically devoted to studying the relationship between complexity dimensions and reasons for project delay in the ERP system implementation projects context (Baraldi, 2009). The author did recognize limitations of the predominant 'complex product' perspective and introduced user-related complexity dimension. However, other complexity measures were not scrutinized and the study was based on one case study.

2.10. Knowledge gap identification

As it was shown in this chapter, in several studies, various elements of project complexity were identified to be a source of risk of project delay. However, considering the two streams of research, on project complexity and on project delay, it seems that there is a scant literature on the topic regarding the relationship between the two concepts and none of the previous studies tried to look at the impact of project complexity from a holistic point of view, given the comprehensive understanding of the term that had emerged in the literature in the past years.

Thus in the field of project delay, many researchers that tried to identify the causes of project overruns, unveiled several complexity elements such as changed orders (Koushki et al., 2005; Assaf et al., 1995), resources shortage (Faridi & El-Sayegh, 2006; Sambasivan & Soon, 2007), design complexity, (Toor & Ogunlana, 2008), lack of experience (Lim & Mohamed, 2000; Sambasivan & Soon, 2007), lack of communication (Sambasivan & Soon, 2007) or even complexity categories such as structural complexity and uncertainty (Williams, 2005). However, most of the studies focused mainly on industry specific factors as the scope of their research did not include the study of project complexity. Furthermore, even the authors that focused on the aspect of complexity did not study it from a holistic point of view, often disregarding the elements of perceived/subjective complexity.

On the other hand, in the field of project complexity, researchers were mainly concerned with the development of complexity assessment frameworks that would help project managers pursue an active management, tailoring the resources and capabilities to the needs of each project, in order to decrease the probability of not meeting the established objectives in terms of time, cost and quality. Thus, although researchers acknowledged the impact of project complexity in achieving the established performance parameters, few of them tried to analyze the nature of this relationship. To the best of our knowledge, the work done in this respect is limited to the study of the relationship between project's network morphologic complexity and the uncertainty concerning the total duration of the project, which was done in the Operations Research field.

Thus, the present research aims to fill this gap of knowledge, by studying the relationship between project complexity and the risk of delay, by considering the wide range of complexity elements that were identified by Geraldi et al. (2011) in one of the most recent and inclusive reviews on the topic of project complexity. Thus, the study will look at project complexity from a holistic perspective, covering all four categories that were identified earlier in this chapter: structural complexity, uncertainty perceived/subjective complexity and dynamics.

However, an important aspect that must be taken into consideration in pursuing such a study is the contextual nature of complexity. While Chu et al. (2003, cited in Vidal & Marle, 2008, p. 1098) considers contextuality to be "a common denominator for any complex system, Koivu et al. (2004, cited in ibid) state that the "practices that apply to one project are not directly transferable to other projects with different institutional and cultural organizations" (p. 1098). Therefore, in order to attain consistency in findings it is important to conduct the research in a specific context, and thus the study will be focused on a specific industry.

As it was previously highlighted, in the ERP industry, projects seem to have one of the highest rates of failure, entailing significant delays. Furthermore the ERP-implementation projects seem to reunite all categories of complexity and thus represent suitable context to study the relationship. First, they employ numerous resources and a significant degree of variety and interconnectedness between system elements. Second, ERP-implementation project have a high degree of customization, bringing novelty elements. Third, given the high level of business transformation their implementation usually brings and the high stakes, the social-political factor play an important role as these types of projects are frequently accompanied by conflicts of interests and resistance to change. Furthermore, it often happens that various unplanned changes occur during the implementation process, such as changes in stakeholders' interests and subsequently in project requirements. Therefore, considering the aim of the present study, it seems that the ERP industry entails a favourable context to conduct research.

Hence, given the gap of knowledge identified in the literature, the research will analyze the relationship between project complexity, in its holistic sense, as derived from a broad literature review performed by Geraldi et al. (2011), and the risk of delay, by investigating a number of ERP-implementation projects.

CHAPTER 3 – RESEARCH METHODOLOGY

3.1. Introduction

This chapter will discuss the research methodology, which according to Reminiy et al. (1998, p. 28) represents the procedural framework within which the research is conducted. The structure of the chapter will follow the layers of the research 'onion' proposed by Saunders et al. (2003, p 83), which depicts in detail the research philosophy, research approaches, research design and research tactics of the study.

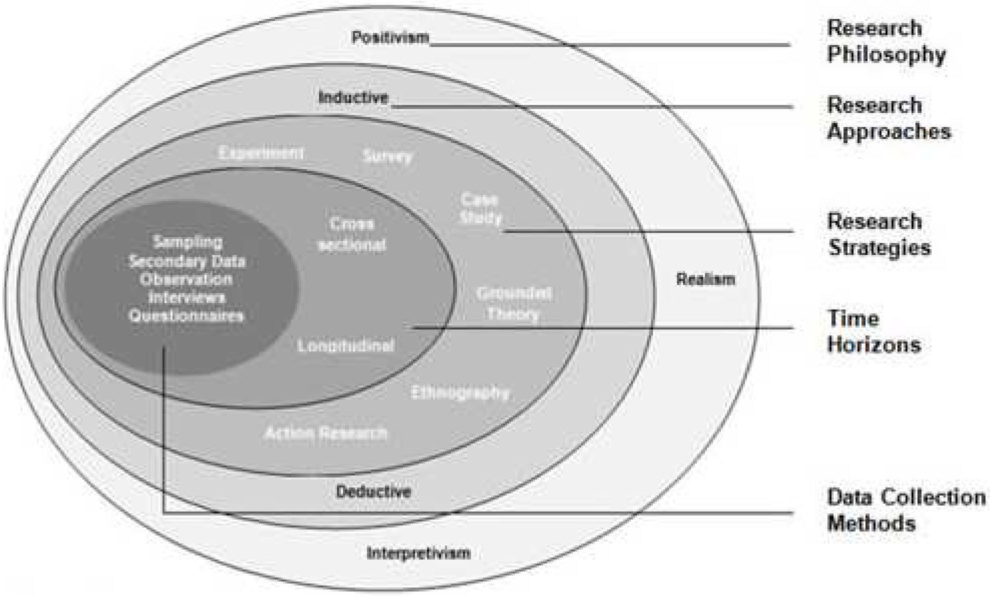

Figure 4. The research 'onion'. Source: Saunders et al. (2003, p. 83)

3.2. Research philosophy

The first layer is the research philosophy, representing the foundation of the research process. The research philosophy depicts the underlying assumptions about the world that will dictate the research strategy and research methodology of the study, delineating researchers' standing in regards to the development of knowledge and its nature (Saunders et al., 2009, p. 108). Guba & Lincoln (1994), define this paradigm as the "basic belief system based on ontological, epistemological and methodological assumptions" (p. 107). Considering the fundamental role of the philosophical orientation to the research process, with a tremendous impact on the way the research is understood, it is important not only to establish it at an early stage, primary to the choice of research methods (Remenyi et al., 1998, p. 37; Saunders et al., 2009, p. 108), but also to explicitly state it, in order to avoid ambiguity and to enhance the sense making process of the study's findings (Biedenbach & Müller, 2011, p. 83). There are three predominant philosophical stances in the literature that follow the traditional view of coherence between ontology, epistemology and methodology underpinning the validity of the study: positivism, realism and interpretivism (Biedenbach & Müller, 2011; Saunders et al., 2009; Bryman & Bell, 2008).

3.2.1. Ontological considerations

Ontology entails the study of being, referring to the researcher's perspective of the world, in regards to the nature of reality. Thus the researchers can look at the surrounding environment through an objective lens, regarding the social entities as having a reality independent of its actors, or they can look through a subjective lens, considering the reality to be constructed around the perceptions and actions of individuals (Bryman & Bell, 2008, p. 19; Saunders et al., 2009, p. 110).

Objectivism

Objectivism is an ontological position that considers the social phenomena to exist outside of the reach and influence of individuals, leading the assumption that there is only one reality (Bryman & Bell, 2008, p. 19; Biedenbach & Müller, 2011, p. 86). Thus, reality is not a function of individuals' ideas; it is reflected in facts, which are isolated from attitudes and feelings.

Subjectivism

Subjectivism, which is often associated with the term constructionism, is an ontological position that considers social phenomena to be a result of individuals' conceptualizations of reality and their subsequent behaviour (Saunders et al., 2009, p. 111). As each social actor comprehends reality in a different way, according to his or her mental model (Jaafari, 2003, p. 49), the subjectivist stance entails multiple realities, which have an emergent nature, as the individuals' perceptions are influenced by their different experiences and interactions with other actors. The researchers that have a subjectivist view of the world are interested in understanding the realities of the individuals and the motivations behind their behaviours.

The ontological position taken in this research is subjectivism as it encompasses the complex nature of the world, by exploring individuals' interpretations and perceptions of phenomena. Thus the simplistic view of the world offered by objectivism is considered inappropriate, especially in the context of growing complexity at the societal level, which is deemed to maintain in the future, as it was shown in the literature review chapter.

3.2.2. Epistemological considerations

Epistemology is concerned with what represents appropriate knowledge in an area of study, the social world in this case (Bryman & Bell, 2008, p. 3; Saunders et al., 2009, p. 112). A researcher that has an objective view of the world will consider facts to be the sole reflection of reality and will analyze them in isolation from individuals' feelings and attitudes, making use of the principles and procedures applied in the natural sciences and thus embracing a positivist philosophy. On the other hand, a researcher that has a subjective view of the world will try to develop knowledge based on individual's feelings and attitudes, as reflections of their realities and thus adopting an interpretivist philosophy (Saunders et al., 2009, p. 113).

Positivism

Positivism is an epistemological position that aims to discover universal rules and principles (Smyth & Morris, 2007, cited in Biedenbach & Müller, 2011, p.86) by studying observable phenomena in a value free manner (Saunders et al., 2009, p. 114; Bryman & Bell, 2008, p. 14). The researcher is looking at reality as composed of objects that can be measured and thus less prone to bias and adopts an independent position in regards to the subject of the research (Remenyi et al., 1998, p. 33). The positivist researcher develops hypothesis based on existing theory and then collects data, which usually has a quantitative nature, in order to test its validity. In order to enhance the replication of the study, the methodology used is highly structured and data is analyzed through the use of statistics or other mathematical models (Gill & Johnson, 2002, cited in Saunders et al., 2009, p. 114). The outcome of the research will further develop the existing theory, creating the premises for new hypothesis formulation. However, it can be argued that complete detachment of researcher from his or her values is not possible and that to a certain extent they are reflected in the choice of research question and methodology (Saunders et al., 2009, p. 114).

Realism

Realism is an epistemological stance that considers truth to be what our senses show us as reality and in the same manner with positivism, adopts an objective view of the world, where objects exist external to the social actors (Saunders et al., 2009, p. 114). Thus it entails similar approaches to data collection and analysis as in the natural sciences (Bryman & Bell, 2008, p. 15). However, unlike the positivist researcher, the realist researcher is biased by world views, cultural experiences and background. There are two prevailing forms of realism that emerged in the literature: direct realism and critical realism. Direct realism considers that our experiences offer a precise image of the world and thus implies that reality can be understood through the use of appropriate measures. On the other hand, critical realism considers the more common direct realism to be superficial as it fails to "recognize that there are enduring structures and generative mechanisms underlying and producing observable phenomena and events" (Bhaskar, 1989, p. 2). Therefore, critical realism supports the view that individuals do not *perceive/experience* things directly, but rather images of things, which implies that they see only a part of a bigger picture (Bhaskar, 1989, p. 2; Saunders et al., 2009, p. 115). It assumes that the experiences of things themselves are immediately followed by mental processes and thus the knowledge of reality cannot be understood independently of individuals. Thus the critical realist researchers aim to understand the structures behind the phenomena they are analyzing and might use theoretical terms in order to build their explanations. Therefore, they are more likely than the positivist researchers in breaking the status quo (ibid, p. 115).

Interpretivism

Interpretivism is an epistemological position that puts accent on the distinctiveness of individuals, trying to get a deeper insight of their behaviour. The quintessence of the interpretivist view is that each human being has own social reality, which has a specific meaning, given their perception and interpretation of the world that determines their behaviour (Schutz, 1962, p. 59; Bogdan & Taylor, 1975, pp. 13-14). Therefore, the interpretivist researchers focus on the details of a situation and the reality behind them, aiming to understand the meanings individuals attach to phenomena, in order to interpret their actions, to see what makes them take certain decisions and behave in a certain way (Biedenbach & Müller, 2011, p. 86). There are three levels of interpretation: first is the individuals' interpretation of the world, second is the researcher's interpretation of individuals' points of view, which is further interpreted in terms of concepts and theories (Bryman & Bell, 2008, p. 18). Thus the nature of the research is subjective as the researcher cannot be detached of what is being studied. Hence, the interpretivist epistemology lies at the antipode of positivism, considering that the social world is too complex to be narrowed down to a set of laws, like in the natural sciences.

In line with the view that social actors construct their reality through their interactions with the environment and that projects are socially constructed entities (Lundin & Söderholm, 1995, cited in Maylor et al. 2008, p. S17; Cicmil et al., 2006), the study will take an epistemological stance closer to interpretivist, scrutinizing participants' view on a number of projects in order to answer the research question. The interpretivist stance brings several advantages over positivism, as it allows researchers to conduct an in-depth study, preventing the loss of eloquent insight through reductionist approaches by portraying a holistic picture of the context. Furthermore, as it acknowledges the complexity of social actions, it can bring to light interesting findings that would not have been otherwise hypothesized.

3.3. Research approach

After defining the research philosophy of the study it is important to establish the research approach that will underpin the choice of research design, taking into considerations the constraints of the research. According to Easterby-Smith et al. (2008, cited in Saunders et al., 2009, p. 126) the designation of the research approach will shed light on a number of matters such as: what data will be required to answer the research question and how will it be analyzed; whether the research aims to gain a better understanding of the phenomena rather than to describe it. There are two fundamental research approaches in the literature: *deductive* and *inductive*.

The *deductive* approach is mainly associated with the positivist stance as it is typically used when the research is guided by theory and laws represent the basis of explanation, permitting the prediction and control of phenomena (Collis & Hussey, 2003, cited in Saunders et al., 2009, p. 124). Thus the researcher develops a hypothesis on the basis of the existent theory, which is then subject to empirical scrutiny, in order to be either rejected or confirmed (Bryman & Bell, 2008, pp. 9-10). The deductive approach seeks to explain causal relationship between variables, which is initially presumed in the hypothesis. Furthermore, the hypothesis needs to translate concepts into operational terms in order to be quantified, following the reductionism principle. Saunders et al.

(2009, p. 125) underlines several characteristics of deduction: replicability, objectivity and generalizability. In this respect it uses a highly structured methodology, ensures researcher's independence of what is being observed and requires large samples.

The *inductive* approach on the other side is used when theory is the outcome of the research, thus being usually associated with the intepretivist stance (Bryman & Bell, 2008, p. 3). In this case the researcher aims to develop an understanding on how individuals perceive their social world, making generalizable inferences out of the observations (Saunders et al., 2009, p. 126). Hence, the researcher puts a great emphasis on understanding the context of the observations, developing an in-depth study, out of which alternative explanations might emerge. In order to gain a deeper insight and look at the phenomena from different perspectives, the researcher is likely to use a variety of methods for the data collection, which are usually applied to a small sample of observations (Saunders et al., 2009, p. 127).

In line with the interpretivist philosophy underpinning this study, the main approach adopted in the current research will be the inductive approach. Considering the aim of the research, to attain a deep understanding of the relationship between project delay and its level of complexity, a deductive approach would not have been suitable due to its rigid methodology and its limitations stemming from the operationalisation of concepts under pre-established definitions. Furthermore, as the topic became popular only in the beginning of the new millennium, there is a lack of supporting theories and empirical studies, which hinders the formulation of initial hypothesis. Although we do start with a wider frame of references from the literature review, it does not play a role of rigid theory or hypothesis to be tested. Instead, it is used as a starting point and various data collection methods will be pursued in order to look at the phenomenon from different angles and to finally draw inferences.

3.4. Research strategy

The following two layers of the research 'onion' portray the research design, which, according to Robson (2002), represents the overall plan of "turning the research question into a research project" (Saunders et al., 2009, p. 136).

The research question, the purpose of the research, the amount of existing knowledge, as well as the philosophical orientation will have a strong mark on the choice of research strategy (Saunders et al., 2009, p. 141). There are several research strategies that can be pursued when conducting a study, each of them entailing different means of collecting and investigating data. Nonetheless, while there is a great overlap amongst the research strategies, each of them has its own strengths and weaknesses (Yin, 2009, pp. 6-8). Thus, there is no superior research method and the suitability of a strategy is rather a matter of context, since different methods accommodate different research needs. Furthermore, Saunders et al. (2009, p. 141) argue that these strategies are not mutually exclusive and researchers have the possibility to use a secondary strategy under the umbrella of the main one.

In order to facilitate the decision process regarding the research strategy, Yin (2009, p. 8) identifies three main criteria of differentiation between various research methods: the nature of the research question, the researcher's degree of control over the behavioural events and the temporal nature of the data – historical vs. contemporary (Fig. 5).

Strategy	Form of research question	Requires control over behavioural events?	Focuses on contemporary events?
Experiment	How, why	Yes	Yes
Survey	Who, what, where, how many, how much	No	Yes
Archival analysis	How, why	No	Yes/No
History	How, why	No	No
Case study	How, why	No	Yes

Figure 5. Relevant situations for different research strategies. Source: Yin (2009, p. 8)

The present study has an explanatory purpose, as its aims to understand and recognize the causal linkages between the project complexity and the risk of delay, by investigating the reasons of delays in several ERP project, gaining an insight on their level of complexity and finally understanding how does project complexity influence projects' time performance. Thus, the research question could be translated into: "How does the degree of project complexity affect ERP projects' time performance?".

As it can be seen from Fig. 5, the case study, history and experiment strategies fit better the explanatory nature of the questions "how" and "why". However, the history strategy is usually preferred when the researcher wants to analyze data from the past, particularly when only secondary data is available (Yin, 2009, p. 11). In the present study such a strategy would have been limitative, since a deeper insight on the reasons of delay could be gained from interviewing the responsible project managers. Furthermore, the experiment strategy is pursued when the researchers have precise and systematic control over the behavioural events (ibid, p. 11), which is not achievable considering that the studied concepts (e.g. complexity) are subjective in nature. On the other hand, the case study strategy is selected when researchers examine contemporary events and have no access and control over the relevant behaviours (Yin, 2009, p. 11), as it seem to be the case in the current research.

Furthermore, the case study strategy entails an additional set of characteristics that support the aim of the study and its philosophical underpinnings. According to Robson (2002, p. 178), the case study is a "strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence". In line with the interpretivist position of the present research, the case study strategy is recommended for gaining a deep insight of the research context, being particularly useful for understanding complex social phenomena (Yin, 2009, p. 4). By allowing researchers to deal with a variety of data collection techniques (i.e. interviews, documentary analysis, questionnaires), it provides different perspectives of the analyzed phenomena, giving a holistic view of the situation.

Case study design

Yin (2009, p. 46) distinguishes between single case study and multiple case studies designs. He identifies several instances when the single case study is the appropriate design to pursue. Thus if the case study is critical, unique, representative, revelatory or longitudinal, there is no need for comparison with a second case study. As it has been shown in the literature review chapter, little study has been done on the topic in the past and thus there is no well-formulated theory from which to draw hypothesis, meaning that the critical condition is not met. Furthermore, ERP systems have been implemented in organizations for a long time, becoming a common practice and thus the analyzed situation is neither unique nor revelatory. However, as IT projects are contextualized endeavours, it would be difficult to name a certain project to be representative. In addition to that, the research does not aim to analyze the projects at different points in time and thus a longitudinal study will not be pursued.

Therefore, the context of the research does not meet any of the criteria that support the single case study design. Furthermore, such a design would entail a very strong justification for choosing a particular case as there is a high risk of misrepresentation (Yin, 2009, p. 50). Thus a multiple-case study design will be pursued in order to produce more robust and generalizable findings as a result of the underlying replication logic.

3.5. Time horizons

Since the aim of the research is to explain how project complexity and the delay are related, the studied projects have to record delays, the fact which is only known after the projects' completion. Therefore, the research will provide a snapshot of the projects, taken after the closure stage, indicating the cross-sectional study. At that time, interviewees would have a broad overview of the projects and a deeper understanding gained in the lessons learned process.

Although the changes occurred during projects lifecycle will certainly be a point of interest, they do not represent the main focus of the research. Furthermore, given the time constraints of the research, it would not have been possible to pursue a longitudinal study.

3.6. Research tactics

After establishing the research philosophy and the research design of the study, the research tactics must be designated. Standing in the centre of the research 'onion', the research tactics encompass the data collection instruments and the subsequent analysis techniques that will be employed, at their higher level of detail (Saunders et al., 2009, p. 138).

3.6.1. Type of data collected

Regarding its nature, the collected data can be either quantitative or qualitative. Quantitative data concerns numeric data, which is usually preferred by the positivist due to its objective nature. On the other hand, qualitative data refers to non-numeric data which is usually favoured by the interpretivist researchers, given its ability to capture a wide variety of information, regardless of its quantifiable nature. Thus qualitative data can be found in various forms, such as words, pictures etc.

Considering the debate in the literature on project complexity, between the holistic perspective of the Project Management versus the mathematical perspective of Operations Research, the present study aims to analyze the concept from a more qualitative point of view. Although both qualitative and quantitative data will be collected, the latter will be analysed from a qualitative perspective, being used as a mean to understand the interviewees' perception on the level of project complexity.

3.6.2. Data collection methods

There is a multitude of data collection methods which have both advantages and disadvantages. According to Yin (2009, pp. 114-115), one of the main advantages brought by the case study strategy lies in the possibility of using multiple sources of information as it leads to the "development of converging lines of inquiry". Therefore, when adopting the principle of triangulation, a higher degree of research's findings credibility is achieved, as they stem from the multiple sources of evidence. In this respect, two primary data collection methods will be pursued in the present study, specifically two types of interviews. Considering the accent put on the holistic perspective of project complexity, in order to answer the research question, it is important to collect information about all the complexity categories identified in the literature review. In order to ensure this aspect, the interviews will be guided by the authors, in the form of semi-structured interviews and questionnaires (structured interviews).

Table 2. Types of Evidence. Source: Yin (2009, p. 102)

Source of Evidence	Strengths	Weaknesses
Documentation	• stable - repeated review • unobtrusive - exist prior to case study • exact - names etc. • broad coverage - extended time span	• retrievability - difficult • biased selectivity • reporting bias - reflects author bias • access - may be blocked

Archival Records	• Same as above • precise and quantitative	• Same as above • privacy might inhibit access
Interviews	• targeted - focuses on case study topic • insightful - provides perceived causal inferences	• bias due to poor questions • response bias • incomplete recollection • reflexivity - interviewee expresses what interviewer wants to hear
Direct Observation	• reality - covers events in real time • contextual - covers event context	• time-consuming • selectivity - might miss facts • reflexivity - observer's presence might cause change • cost - observers need time
Participant Observation	• Same as above • insightful into interpersonal behaviour	• Same as above • bias due to investigator's actions
Physical Artifacts	• insightful into cultural features • insightful into technical operations	• selectivity • availability

Semi-structured interviews

An interview is a “purposeful discussion between two or more people” (Kahn & Cannell, 1957, cited in Saunders et al., 2009, p. 318), which is often used as a data collection method as it enables researchers to gather valid and reliable data for the purpose of their study (ibid, p. 318). Yin (2009, p. 108) emphasizes their relevance for the case study strategy as it provides significant insight regarding humans’ perceptions and behaviours. According to Saunders et al. (2009, pp. 323-324), the semi-structured interview is the most frequent type of interview in explanatory studies as it allows researchers on one hand to infer causal relationships between variables and on the other to explore participants attitudes, opinions and reason for decisions.

Furthermore, semi-structured interviews are recommended in the study of complex phenomena as they allow researchers to collect a consistent and detailed set of data, given their qualitative nature, through the mean of open ended questions (ibid, p. 323). Although there are certain pre-established areas and questions to be covered, the unstructured nature of the interviews will allow researchers to guide the discussion in new areas that emerge from interviewees’ answers and seem to be relevant for answering the research question. The emergence of new knowledge is highly likely especially in the cases where there is little theory or empirical evidence on the topic, as it is in the case of the project complexity impact on the risk of delay.

Moreover, given the interactive nature between researcher and the interviewee, there is a higher degree of trust from the latter one in the way data will be used, thus decreasing his or her reluctance in disclosing certain information (Saunders et al., 2009, p. 324).

In the current study, nine semi-structured interviews will be conducted with project managers and senior consultants responsible for ERP system implementation projects (which recorded delays) in four consulting companies. The researchers will seek to understand what the reasons for project overruns were and what role did project complexity play in the occurrence of delays. In order to avoid response bias, the interviews will consist of open ended questions that will not contain leading elements (Appendix 1).

Questionnaires

A questionnaire will be administered to the participants after the semi-structured interviews have been conducted. The aim of the questionnaire is to gather opinion data in regards to the elements of project complexity that were present in the ERP-implementation projects. Therefore, a list of project complexity parameters are drawn from the literature, which will be subject to interviewees' appraisal, each element being evaluated on a scale from 1 to 5, for each project in question. The purpose of the questionnaire is to provide an alternative picture of the projects' level of complexity. Thus it can also be considered to play the role of a checklist, aiming to shed light over the complexity factors that were present in the projects but were omitted in interviews. Nonetheless, the questionnaire will portray the level of complexity of the projects, showing as well the role played by the individual factors, as perceived by the interviewees. The questionnaire has two purposes: to provide another data collection method for triangulation and to distinguish between conscious or perceived and subconscious complexity (categories and factors mentioned by interviewees themselves in connection to the delay versus factors that seemed to influence project delay as result of comparison of several projects, but not conceived as such by the PMs). The questionnaire data will not be subject to statistical analysis.

3.6.3. Sampling approach

The sampling techniques play an important role in ensuring the research credibility, and according to Miles & Huberman (1994, p. 27) "your [sampling] choices ... all place limits on the conclusions you can draw, and on how confident you and others feel about them". The sound sampling approach should be in fit with the research question, research approach, research strategy, type of data to be collected and the intended method of analysis (for instance, statistical inference would require probability sampling).

Generally, the sampling approaches and techniques can be divided into two main categories (Saunders et al., 2009, p. 213): (1) probability ('representative') sampling and (2) non-probability ('judgmental') sampling (Fig. 6).

The probability sampling is used when the research question implies a statistical inference analysis to answer the question and thus often related to survey and experimental research strategies (ibid, p. 213), and, therefore, the non-probability sampling is adopted in the research, reflecting its inductive and qualitative nature. This is in line with Miles & Huberman (1994, p. 27) discussion on common characteristics of qualitative research samples, which include small size and their purposive theory-driven selection. Furthermore, there are no clear rules to determine the right sample size for non-probability sampling techniques (unlike the probability sampling) except a notion that the data saturation has to be reached, i.e. when additional interviews does not bring new insights (Saunders et al., 2009, pp. 233-235).

Further, the non-probability sampling approach adopted in the study is **purposive**, since its aim is to explore particular phenomenon (delays in complex projects) in a certain setting (ERP-implementation projects), and the cases sampled should exhibit the phenomenon. The purposive sampling approach particularly suits the case study research strategy (Saunders et al., 2009, p. 237). Finally, the sampling is homogenous, since we should concentrate on the particular sub-group (ERP-projects implemented by IT-consultants) to study it in-depth (ibid, p. 240). However, the sampling in the research has also some traits of snowball approach, since the first interviewees provided the researchers with further contacts to similar cases.

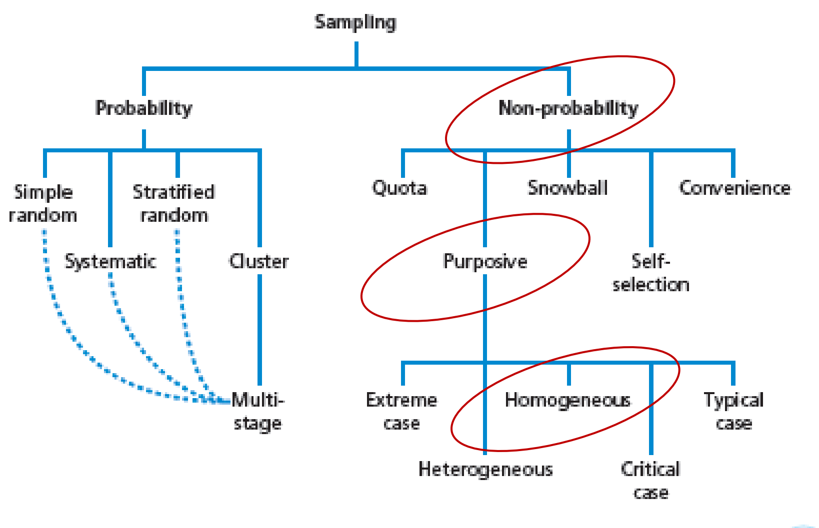

Figure 6. Sampling approaches. Source: Saunders et al. (2009, p. 213).

Another classification of sampling approaches described by Miles & Huberman (1994) is presented in Table 3. According to it, the sampling approach undertaken in the study has characteristics of three types: homogenous, theory-based and snowball.

Table 3. Typology of sampling strategies in qualitative inquiry. Source: Miles & Huberman (1994, p. 28)

Type of sampling	Purpose
Maximum variation	Documents diverse variations and identifies important common patterns
Homogeneous	Focuses, reduces, simplifies, facilitates group interviewing
Critical case	Permits logical generalization and maximum application of information to other cases
Theory based	Finding examples of a theoretical construct and thereby elaborate and examine it
Confirming and disconfirming cases	Elaborating initial analysis, seeking exceptions, looking for variation
Snowball or chain	Identifies cases of interest from people who know people who know what cases are information-rich
Extreme or deviant case	Learning from highly, unusual manifestations of the phenomenon of interest
Typical case	Highlights what is normal or average
Intensity	Information-rich cases that manifest the phenomenon intensely, but not extremely
Politically important cases	Attracts desired attention or avoids attracting undesired attention
Random purposeful	Adds credibility to sample when potential purposeful sample is too large
Stratified purposeful	Illustrates subgroups; facilitates comparisons
Criterion	All cases that meet some criterion; useful for quality assurance
Opportunistic	Following new leads; taking advantage of the unexpected
Combination or mixed	Triangulation, flexibility, meets multiple interests and needs
Convenience	Saves time, money and effort, but at the expense of information and credibility

Following the sampling process presented above, Table 4 represents the list of projects chosen in order to conduct the study. In order to support homogeneity of the sample only the projects carried out in one country (Russia) were selected for the study. Further, a short description of the consulting companies which executed the projects is presented in Table 5. Due to the ethical considerations, the names of the companies will not be disclosed, as they asked to remain anonymous. This decision is understandable considering the nature of the issues discussed (project failures in form of delays) and the emphasis the consulting companies put on reputation.

Table 4. Description of the projects

Project #	Company	Role of the interviewee	Client's industry	Country
1	Company 1	Project manager	Aviation	Russia
2	Company 2	Project manager	Food & Beverages (coffee & tea)	Russia
3	Company 2	Project manager	Food & Beverages (confectionary)	Russia
4	Company 2	Senior consultant	Metallurgy	Russia
5	Company 3	Project manager	Oil industry	Russia
6	Company 3	Project manager	Oil industry	Russia

7	Company 2	Senior consultant	Food & Beverages (Soft drinks)	Russia
8	Company 4	Project manager	Telecom	Russia
9	Company 1	Project manager	Machine building (tractors)	Russia

Table 5. Short description of the consulting companies

Company code	Company description
Company 1	Medium scale IT-consulting company employing over 50 consultants and specializing on ERP-system implementation projects for industrial domestic companies in Russia. Clients vary from medium scale auto component manufacturer to a large integrated airplane plant. Established in 2006. Official partner of SAP AG.
Company 2	A Global business solution company, with $100 bln. in revenues and offices all over the world. ERP system implementation business line represents one of the important directions for the company.
Company 3	One of the global 'Big4' auditing companies, encompassing a strong ERP systems implementation business unit. Works predominantly with large clients, either with multi-national companies or national 'champions'.
Company 4	US software vendor and consulting company predominantly focused on IT-solutions for Telecom industry (e.g. ERP systems, billing systems etc.). Works with large clients, either with multi-national companies or national 'champions'.

3.6.4. Data analysis

According to the overall research plan outlined, a qualitative analysis of the data will be pursued. This includes categorization of the data and recognizing causal relationships between categories.

The study includes both deductive and inductive components (building-up on the existing theory), with the emphasis on the latter. This duality is incorporated well within template analysis approach (Saunders et al., 2003, pp. 395-396). It will start with pre-determined list of codes, which then will be amended after the data collection and the analysis. According to this, the researchers will start with a theoretical framework (on the main categories of complexity – structural, uncertainty, dynamic etc.) drawn from the literature, but it well may be the case that new categories or links can arise as a result of the data analysis, reflecting the inductive character of the research.

The interviews will be transcribed and codified in order to identify the relevant complexity dimensions and to relate them to reasons of delay. Apart from this, the transcripts will be scrutinized in order to identify possible new categories or parameters, which were not found in the literature. Thus, the identified categories and linkages will be compared among the cases as well as with existing studies. Although part of the data will be expressed in numbers (e.g. questionnaire results) it will be understood and analyzed as qualitative data since 'number depends on meaning' (Dey, 1993, cited in Saunders, 2003, p. 378). Furthermore, the analysis will aim to understand and recognize the relationship between the project complexity and delay by *analytical inference*, rather than a statistical one.

3.7. Credibility of the research findings

The credibility of research findings is the main attribute which characterizes a research value and the main difference which "distinguishes a Nobel Prize winning study from a newspaper article" (Müller, 2011). Research methodology plays crucial role in ensuring the credibility by reducing the possibility of getting the answer wrong (Saunders et al., 2009, p. 156). The two components of credibility, reliability and validity and the tactics undertaken to ensure them are discussed below. These tactics are developed to address four criteria which are broadly used in order to determine quality of social research (Yin, 1989, pp. 40-41).

3.7.1. Reliability

Reliability is related to the extent to which the research design allows to repeat the research operation and to get consisting findings (Saunders et al., 2009, p. 156). Generally, it can be assessed by considerations whether the same results will be obtained at different moment of time or by other researcher and is there a transparency in how conclusions were drawn out of the data collected (Easterby-Smith et al., 2008, cited in Saunders et al., 2009, p. 156). There are four main threats to reliability: participant error, participant bias, observer error and observer bias (Robson, 2002, p. 102). The measures undertaken to ensure reliability of the research are presented in the Table 6, following framework suggested by Yin (2003, p. 34).

Table 6. Reliability test (after Yin, 2003, p. 34)

Tests	Tactic	Phase	Measures undertaken
Reliability	Develop case study database	Data collection	The database was created for each case study in question. It contains all information collected, particularly transcripts of interviews and questionnaire responses. Creating the database was aimed to enhance reliability of the research

3.7.2. Validity

According to Saunders et al. (2009, p. 157) "validity is concerned with whether the findings about what they appear to be about". Robson (2002, p. 101) outlines the connection between the concepts claiming that reliability is necessary albeit not sufficient condition to ensure validity.

There are a number of threats to the validity (Robson, 2002, pp. 103-108), and each of these in a certain way can distort the research findings. For instance, such influence can be related to certain events in the past, influencing the parameters in question ("history") or influence of the awareness of the interviewees that they are researched ("testing"), especially in the case when it may disadvantage them (ibid).

In regard to the concept, there are three notions each of which deserves explicit attention during the research design (Yin, 1989, p. 41), specifically construct validity, internal validity and external validity (generalisability). The author describes the notions as follows:

> "*Construct validity*: establishing correct operational measures for the concepts being studied;
>
> *Internal validity* (for explanatory or causal studies only, and not for descriptive or exploratory studies): establishing a causal relationship, whereby certain conditions are shown to lead to other conditions, as distinguished from spurious relationships;
>
> *External validity*: establishing the domain to which a study's findings can be generalized" (Yin, 1989, pp. 40-41)

The measures that are needed to ensure validity are indeed contingent upon particular research strategy adopted as well as its philosophical underpinnings. The measures undertaken to ensure reliability of the research are presented in the Table 7, following the framework presented by Yin (2003, p. 41).

Table 7. Validity test (after Yin, 2003, p. 34)

Tests	Tactic	Phase	Measures undertaken
Construct validity	• Use multiple sources of evidence • Have key informants review draft case study report	Data collection Composition	Two sources of evidences are used in the research, including semi-structured interviews and questionnaires for each project in question. Although informants did not read the report in full, they did review interview summary. In certain cases there were short follow-up interviews as well. These measures helped to ensure that our understanding corresponds to the interviewees' perception.
Internal validity	• Do pattern-matching	Data analysis	The frame of reference used to do pattern-matching was developed as a result of the literature review and consist both from the complexity categories and the complexity parameters.

			Consequently, the rival explanations of the common outcome (delay) were its dependence on each of the categories. The results are compared across the cases to ensure that the causal relationship is valid (Yin, 1989, p. 111)
External validity	• Use replication logic in multiple-case studies	Research design	As it was stated in the research strategy section, the study represents “multiple-case study”. The ‘homogenous’ choice of companies (IT-consultancy) and the similar type of projects (ERP-system implementation) was aimed towards replication of the study. At the same time, within this homogenous set the contexts were quite diverse (e.g. in terms of client’s industry) to support generalisability.

The present chapter presented the research methodology of the study following the research ‘onion’ model (Saunders et al., 2003, p. 83) and explaining the rationale for the methodological choice at each layer of the ‘onion’. It started with the discussion of philosophical considerations underpinning the study and concluded with the research tactics and data collection methods. The coherence between different layers’ choices was discussed throughout the chapter and it is considered to be the foundation for the study findings credibility. The following chapter will expand on the data analysis methodology (template analysis) discussion in a more detailed way, and will conclude with the research findings.

CHAPTER 4 – DATA ANALYSIS

4.1. Data analysis process

As it was mentioned in the Methodology chapter, the present study will pursue a template analysis approach, given its qualitative nature and the mix of deductive and inductive components. This approach involves data categorization into a set of pre-establish codes, which is subject to amendments according to the findings that emerge in the data collection and analysis process (Saunders et al. 2009, p. 506). One of the main advantages of the template analysis is that it offers a certain degree of flexibility, as on one hand it allows researchers to select a set of themes to explore and on the other it gives them the possibility to investigate emergent issues that were not considered in the beginning (King, 2004, cited in Saunders et al. 2009, p. 508).

Given the traits of the case study strategy, data has been collected from multiple sources: semi-structured interviews and questionnaires. Thus each set of data will be first analyzed individually and afterwards the findings from the two sources will be triangulated. The steps of the data analysis that will be followed are presented in the Figure 7 below.

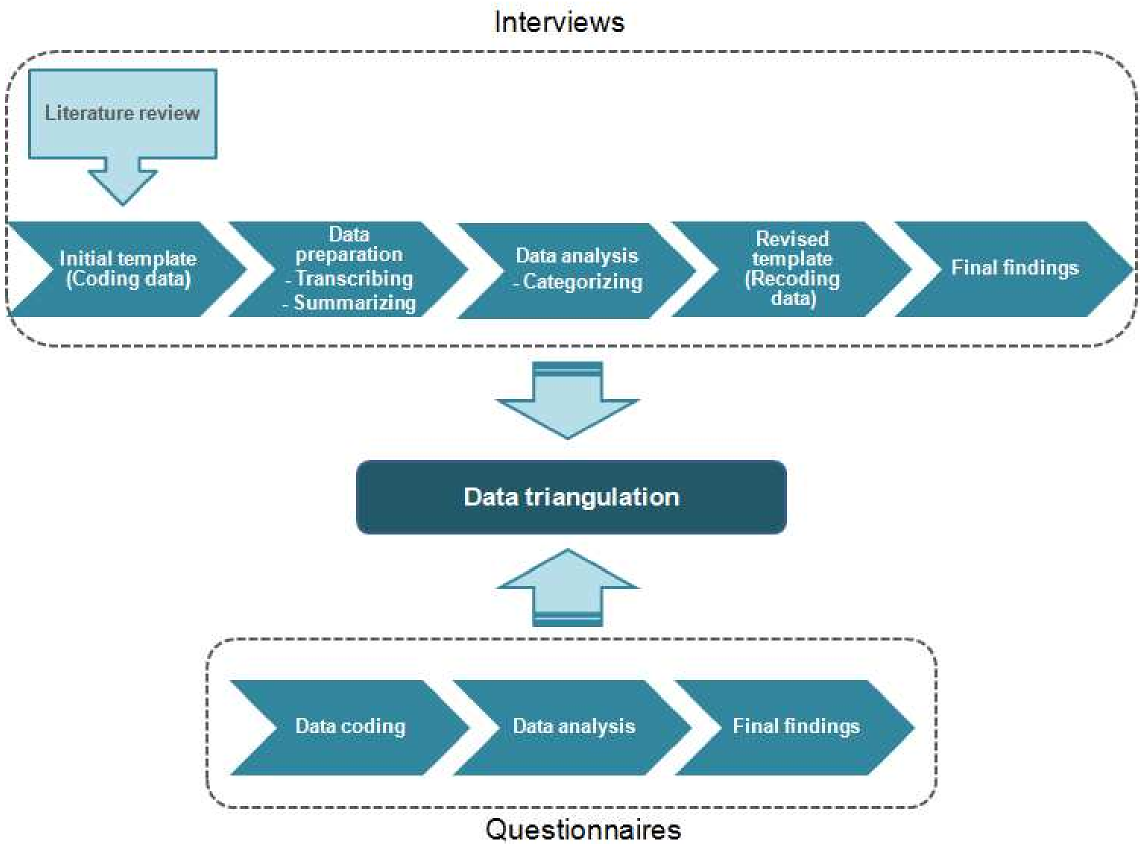

Figure 7. Data analysis process (developed by the authors)

Analysis of data collected through semi-structured interviews

On the basis of the literature review, an initial template was developed, showing the categories that were expected to occur in the data collection process and the hierarchical relationship between them. As the semi-structured interviews were focused on two main streams of information, namely reasons for delay and complexity elements that characterized the projects, a set of codes was developed for each line of inquiry. These sets of codes determined the main points brought into discussion with the interviewees. However, the interactive nature of the interviews allowed researchers to investigate new relevant topics that arose in the process.

After the data collection process has been completed, the data preparation process was followed. First, the semi-structured interviews were transcribed from audio-recordings in order to allow an elaborated analysis. Given the non-standardized and complex nature of the data collected (Saunders et al., 2009, p. 482), the data was summarized and only the meaningful and representative quotes were selected for future evidence. This process helped the researchers to have an overview of the main ideas and to spot some broad initial patterns and linkages.

When the data was ready for the analysis, the categorization process was carried out, which involved assigning the pre-established codes to units of data. As the information in the interviews was not recounted in a sequenced manner, its fragmentation did not alter its meaning. During the analysis, some of the codes were modified, elements were rearranged across categories, and new categories and subcategories emerged as there were units of data that did not fit in any of the initial categories. Several new patterns were found, while some categories were not used at all as they did not match any data unit. Thus, the analysis process led to a revised template. When every single unit of data has been analyzed and categorized, the final version of the template emerged.

The outcome of the categorization will be presented in the following subsections, as several tables were developed according to the final template, showing the classification of data excerpts. Lastly, the two sets of data have been compiled into a final table, in order to show the linkages between the codes for reasons for delay and the codes for complexity categories.

According to Yin (2009, p. 160) the analysis of word tables allows the identification of cross-case patterns and the drawing of subsequent conclusions. On the basis of the findings several hypotheses were inferred, that can be subject to future research.

Analysis of data collected through questionnaires

After the semi-structured interviews had been conducted, participants were administered a questionnaire, where they were asked to rate the impact of a set of complexity elements on project delay, using a five point scale, for each of the projects discussed in the interviews. If an element would not be present in the project, the respondent would tick the “Not applicable” box. The data gathered from the questionnaires has been compiled in Appendix 4. After collecting all the questionnaires, data was coded using the actual value indicated by respondents, as shown in the Table 8 below.

Table 8. Questionnaire data coding

Questionnaire coding	
Not applicable	0
Very low	1
Low	2
Medium	3
High	4
Very high	5

The data was analyzed and compared with the table showing the connections between the reasons for delay and the complexity categories that was based on data from interviews. This allowed using triangulation approach to ensure credibility.

4.2. Data templates

4.2.1. Reasons for delay template

Based on Basoglu et al. (2007, pp. 79-80) discussion presented in the literature review, the following initial template for data analysis was developed (Table 9). The reasons are divided into four categories, specifically, technical factors, management and communication factors, goals and scope setting factors and socio-political (soft) factors.

Table 9. Codification of the potential reasons for delay

Potential reasons for project failure (incl. delay)	CODE
1. Technical factors	TECH
1.1. technical complexity of the solutions	COMP.SOL
1.2. inappropriate integration of systems	SYST.INT
1.3. inappropriate customization of ERP	ERP.CUSTOM
1.4. inappropriate process reengineering activities	BPR
1.5. neglect of legacy systems	LEG.SYST
2. Management&Communication factors	MAN.COMM
2.1. poor planning and management	PLAN.MAN.
2.2. losing control over the implementation	CONTROL
2.3. ‘invisibility’ of ERP system	INVISIBL.
2.4. insufficient user training	TRAINING
2.5. inappropriate or insufficient communication	COMMUN.
2.6. inappropriate or insufficient project management	PROJ.MAN.
3. Goals/scope setting factors	GOALS.SCOPE
3.1. Change in business goals during the implementation	CHANGE
3.2. misfit between business requirements and the system functionality	MISFIT
3.3. inappropriate strategic decisions, e.g. on processes reengineering	STR.DECIS.
3.4. lack of investment evaluation regarding the implementation project	INV.EVAL.

3.5. inappropriate ERP package selection	ERP.SELECT.
4. Socio-political/soft factors	SOFT
4.1. lack of client management support	CLIENT.SUP.
4.2. overlooking the people dimension	PEOPLE
4.3. lack of top management support	MNGMT.SUP.
4.4. Lack of user acceptance	USER.ACCEPT.
4.5. neglect of cultural differences	CULTURE

Source: Developed by the authors after Basoglu et al. (2007) discussion

The initial template was used to analyze the interview transcripts by putting the codes next to the relevant excerpts when interviewees mentioned the reasons in relation to their projects. It is worth to be noted, that the reasons listed were developed for all possible 'types' of project failures. Therefore they were not focused specifically on project delays and the intended revision of template is especially important in this case. Further, the revision may include introduction of new dimensions, in case they emerge from the analysis of the data collected, and may entail narrowing down the existing list, given that in our case we consider only a subset of project failures, i.e. project delays.

During the data analysis, several new codes emerged, i.e. there were no suitable codes for the reasons mentioned by the interviewees. For example, an 'ambiguity of contract terms' was one of the major problems in Project 5, causing scope creep and subsequently project delay. Another factor, project 'oversale' (sometimes referring to as 'gold-plating'), meaning promising more than can be accomplished in terms of project duration or system functionality, was mentioned by several interviewees. Furthermore, the factor 'lack of client's staff motivation and involvement' was incorporated in the modified template. Although it could be argued that this factor is implicitly included in the 'overlooking the people dimension' factor, it was mentioned so often in the interviews that it was decided to put it as a separate line. The modified list of possible reasons for delay is presented in the Table 10.

Table 10. Modified codification of the potential reasons for delay

Potential reasons for project failure (incl. delay)	CODE
1. Technical factors	TECH
1.1. technical complexity of the solutions	COMP.SOL
1.2. inappropriate integration of systems	SYST.INT
1.3. inappropriate customization of ERP	ERP.CUSTOM
1.4. inappropriate process reengineering activities	BPR
1.5. neglect of legacy systems	LEG.SYST
2. Management&Communication factors	MAN.COMM
2.1. poor planning and management	PLAN.MAN.
2.2. losing control over the implementation	CONTROL
2.3. 'invisibility' of ERP system	INVISIBL.
2.4. insufficient user training	TRAINING
2.5. inappropriate or insufficient communication	COMMUN.
2.6. inappropriate or insufficient project management	PROJ.MAN.
2.7. Inappropriate working conditions	WORK.COND.
3. Goals/scope setting factors	GOALS.SCOPE
3.1. Change in business goals during the implementation	CHANGE
3.2. misfit between business requirements and the system	MISFIT

functionality	
3.3. inappropriate strategic decisions, e.g. on processes reengineering	STR.DECIS.
3.4. lack of investment evaluation regarding the implementation project	INV.EVAL.
3.5. inappropriate ERP package selection	ERP.SELECT.
3.6. Oversale (gold-plating)	OVERSALE
3.7. Contract ambiguity	CONTRACT
4. Socio-political/soft factors	SOFT
4.1. lack of client management support	CLIENT.SUP.
4.2. overlooking the people dimension	PEOPLE
4.3. lack of top management support	MNGMT.SUP.
4.4. Lack of user acceptance	USER.ACCEPT.
4.5. neglect of cultural differences	CULTURE
4.6. Lack of client staff motivation and involvement	INVOLV.

Colour – new categories

4.2.2. Complexity categories template

The template for the complexity categories was built on one of the most recent and comprehensive reviews on project complexity made by Geraldi et al. (2011). However, as the review comprised complexity elements that were proposed independently by various researchers, there were many duplicates or elements with similar meanings. Thus the duplicates were eliminated and the elements that had commonalities were grouped under an "umbrella" category that would accommodate also their particularities. Furthermore, in the review there were complexity elements with different levels of breadth in terms of connotations. Thus, the complexity elements that had a broad meaning were not included, as their understanding has already been covered by a number of specific elements.

Furthermore, the identified complexity categories were grouped under the main project complexity classes that were identified in the literature review chapter: *structural complexity, uncertainty, perceived complexity, dynamic complexity* and their subsequent subclasses, as it can be seen in Table 11 below. As the dynamic complexity can refer to a change in any element of the previous three categories, Geraldi et al. (2011) considered it too broad to be depicted by complexity elements. Therefore in the initial template this complexity class will not have any subclasses or subcategories.

For each element in the hierarchical list of complexity elements, an abbreviate code was assigned, in order to ease the categorization process of the data units.

Table 11. Codification of potential complexity categories

Complexity elements	CODE
1. Structural complexity	STRUC
1.1. Technological elements	TECH
1.1.1.Breadth of scope	BR. SCOPE
1.1.2.Conflicting requirements	CONFL.REQ.
1.1.3.Number of activities	NO.ACTIV.
1.1.4.Number and variety of technologies involved	NO.TECH.

1.1.5. Systems to be replaced, data misfit, technical and infrastructural integration	SYST.FIT
1.1.6. Technological interdependence	TECH.INTER.
1.1.7. Processes interdependence and integration;	PROCESSES
1.1.8. Variety of distinct knowledge bases (multidisciplinary)	SPECIALT.
1.2. Organizational elements	ORGANIZ.
1.2.1. Team size and number of roles and specializations involved	PR.TEAM
1.2.2. Key experts are available when needed	EXP.AVAIL.
1.2.3. Number of stakeholders and their interdependency	NO.STAKEH.
1.2.4. Concurrent projects and shared resources	CONCUR.PR.
1.2.5. Organizational structure complexity	ORG.STRUCT.
1.2.6. The client and supplier accommodate project well	PR.ACCOMM.
1.3. Contextual elements	CONTEXTUAL
1.3.1. Number of locations and their differences	NO.LOCATION
1.3.2. Multiple time zones, collocation of team members	TIME ZONES
1.3.3. Multi-cultural; multi-language	MULTI-CULT
1.3.4. The project goals are aligned with the organization's strategy	STR.ALIGN.
1.3.5. Health, safety and security, confidentiality, labor/union, legislative compliance	COMPLIANCE
1.3.6. Financial scale	BUDGET
1.3.7. Time pressure (pace of project)	TIME.PRESSURE
2. Uncertainty	UNCERTAINTY
2.1. Epistemic uncertainty – Inexistent information (breakthrough novelty) - Commercial and technological maturity and novelty;	BREAK.NOV.
2.2. Epistemic uncertainty – Imperfect/Unavailable information in the project context	CONTEXT.NOV.
2.2.1. Novelty for stakeholders	STAKEH.NOV.
2.2.1.1. Degree to which technological and organizational aspects are new	NEW.TO.COMP.
2.2.1.2. New organisational structure	NEW.ORG.STR.
2.2.2. Lack of competences	LACK.COMP.
2.2.2.1. Maturity level of the organization with effective change, risk and quality management	ORG.MATURITY
1.1.1.1. Project manager's knowledge and experience	PM.COMP.
2.2.2.2. Stakeholders' knowledge and experience	STAKEH.COMP.
2.2.3. Project element complexity	CLARITY
2.2.3.1. Clarity of project elements - Clear vision, requirements, success criteria and performance measurements	PR.EL.CLARITY
2.2.3.2. Unidentified stakeholders	UNIDEN.STAKE
2.2.4. Data availability - Project data are accurate, timely, complete, easy to understand, credible, available at the right level of detail	DATA.AVAIL.
2.3. Aleatoric uncertainty	ALEAT.UNCER.
3. Perceived complexity	PERCEIV.COMP.
3.1. Common understanding	COM.UNDERST.
3.1.1. Shared vision of the project	SHARED.VISION
3.1.2. Implications of the project are well understood	UNDERST.IMPL.
3.1.3. The line of responsibility for tasks and deliverables is clear in the client's organization	UNDESRT.RESP.
3.1.4. Clarity in respect to organizational and technological setting	SETTING.CLAR.
3.2. Socio-political games	SOC-POL.GAME
3.2.1. Senior management support the project	SEN.MNG.SUPP.
3.2.2. Stakeholders' commitment, involvement, appropriate	STAKEH.COMM.

authority and accountability	
3.2.3. Realistic expectation of stakeholders	REAL.EPXECT.
3.2.4. Conflicts, power struggles and hidden agendas between stakeholders; Hidden agendas	POWER.STRUG.
3.3. Emotional aspects	EMOTIONAL
3.3.1. Communication	COMMUNICAT.
3.3.2. Social integration	SOC.INTEGR.
3.3.3. Personality clashes	PERSON.CLASH
3.3.4. Empathy and transparency in relationship	EMPATHY
4. Dynamic complexity	DYNAMIC.COM

Source: Developed by the authors after Geraldi et al. (2011) discussion

Several new codes emerged during the analysis process, as new patterns were identified. First, the lack of motivation arose as the main source for stakeholders' lack of involvement and commitment, recurring in most of the projects analyzed, and thus the *"Motivation"* category was introduced under Emotional aspects. In addition to that, several subclasses of dynamic complexity emerged from the data collected, the most frequent one being the "*Change in requirements"*. Furthermore, during the analysis it was realized that the initial category "*The client and supplier accommodate project well"* was too broad, gathering under its umbrella a wide variety of elements. In this respect it was divided in two new subcategories "*Human resource availability*" and *"Availability of facilities and other supporting resources"*. As a further consequence the category "*Key experts are available when needed*" disappeared, as it was considered to fit the new emerged category, "*Human resource availability*". Given the fact that the projects have been analyzed from a "post-mortem" perspective, the *"Aleatoric uncertainty"* has been translated into the various changes that occurred during the project life cycle and thus it was considered to be already comprised in the dynamic dimension. Therefore, the initial template was amended according to Table 12.

Table 12. Modified codification of potential complexity elements

Complexity elements	CODE
1. Structural complexity	STRUC
1.1. Technological elements	TECH
1.1.1. Breadth of scope	BR. SCOPE
1.1.2. Conflicting requirements	CONFL.REQ.
1.1.3. Number of activities	NO.ACTIV.
1.1.4. Number and variety of technologies involved	NO.TECH.
1.1.5. Systems to be replaced, data misfit, technical and infrastructural integration	SYST.FIT
1.1.6. Technological interdependence	TECH.INTER.
1.1.7. Processes interdependence and integration;	PROCESSES
1.1.8. Variety of distinct knowledge bases (multidisciplinary)	SPECIALT.
1.2. Organizational elements	ORGANIZ.
1.2.1. Team size and number of roles and specializations involved	PR.TEAM
1.2.2. Human resource availability	HR.AVAIL.
1.2.3. Number of stakeholders and their interdependency	NO.STAKEH.
1.2.4. Concurrent projects and shared resources	CONCUR.PR.
1.2.5. Organizational structure complexity	ORG.STRUCT.
1.3. Contextual elements	CONTEXTUAL

1.3.1. Number of locations and their differences	NO.LOCATION
1.3.2. Multiple time zones, collocation of team members	TIME ZONES
1.3.3. Multi-cultural; multi-language	MULTI-CULT
1.3.4. The project goals are aligned with the organization's strategy	STR.ALIGN.
1.3.5. Health, safety and security, confidentiality, labor/union, legislative compliance	COMPLIANCE
1.3.6. Availability of facilities and other supporting resources	AV.FACILITIES
1.3.7. Financial scale	BUDGET
1.3.8. Time pressure (pace of project)	TIME.PRESSURE
2. Uncertainty	UNCERTAINTY
2.1. Epistemic uncertainty – Inexistent information (breakthrough novelty) - Commercial and technological maturity and novelty;	BREAK.NOV.
2.2. Epistemic uncertainty – Imperfect/Unavailable information in the project context	CONTEXT.NOV.
2.2.1. Novelty for stakeholders	STAKEH.NOV.
2.2.1.1. Degree to which technological and organizational aspects are new	NEW.TO.COMP.
2.2.1.2. New organisational structure	NEW.ORG.STR.
2.2.2. Lack of competences	LACK.COMP.
2.2.2.1. Maturity level of the organization with effective change, risk and quality management	ORG.MATURITY
2.2.2.2. Project manager's knowledge and experience	PM.COMP.
2.2.2.3. Stakeholders' knowledge and experience	STAKEH.COMP.
2.2.3. Project element complexity	CLARITY
2.2.3.1. Clarity of project elements - Clear vision, requirements, success criteria and performance measurements	PR.EL.CLARITY
2.2.3.2. Unidentified stakeholders	UNIDEN.STAKE
2.2.4. Data availability - Project data are accurate, timely, complete, easy to understand, credible, available at the right level of detail	DATA.AVAIL.
3. Perceived complexity	PERCEIV.COMP.
3.1. Common understanding	COM.UNDERST.
3.1.1. Shared vision of the project	SHARED.VISION
3.1.2. Implications of the project are well understood	UNDERST.IMPL.
3.1.3. The line of responsibility for tasks and deliverables is clear in the client's organization	UNDESRT.RESP.
3.1.4. Clarity in respect to organizational and technological setting	SETTING.CLAR.
3.2. Socio-political games	SOC-POL.GAME
3.2.1. Senior management support the project	SEN.MNG.SUPP.
3.2.2. Stakeholders' commitment, involvement, appropriate authority and accountability	STAKEH.COMM.
3.2.3. Realistic expectation of stakeholders	REAL.EPXECT.
3.2.4. Conflicts, power struggles and hidden agendas between stakeholders; Hidden agendas	POWER.STRUG.
3.3. Emotional aspects	EMOTIONAL
3.3.1. Communication	COMMUNICAT.
3.3.2. Social integration	SOC.INTEGR.
3.3.3. Personality clashes	PERSON.CLASH
3.3.4. Empathy and transparency in relationship;	EMPATHY
3.3.5. Motivation	MOTIVATION
4. Dynamic complexity	DYNAMIC.COM

4.1. Change in requirements 4.2. Change in team members and other stakeholders 4.3. Change in strategy 4.4. Change in legislation	CHANGE.REQ. CHANGE.STAKE. CHANGE.STRTG. CHANGE.LEGISL.

Colour – **new categories**

4.3. Reasons for delay

The application of the template is structured according to the main categories of delay factors (the first hierarchical level of the template). For each of these categories there is a table encompassing following columns: code of reason (the second hierarchical level of the template), list of projects where the reason was faced (according to interviews) and evidence (excerpt from corresponding interview). It should be noted, that not all of the reasons presented in the template were encountered during the interviews. Thus such reasons that were not found in the analyzed cases were excluded from the tables.

Technical factors

Intriguingly, the technical factors were mentioned less often than other categories in relation to delays and more specifically appeared in less than half of the interviews. In nearly all cases when technical factors were mentioned, they played an amplifying role for other categories or were strongly related to them. This can be illustrated by an example of Project 1, where seemingly technical reasons for delay were caused by inappropriate communication. On contrary, the interviewees even had a positive attitude to the technical complexity itself stating that "there were some technical difficulties, but it was more interesting than complex". The result of the application of template analysis to the project data regarding technical factors is presented in Table 13.

Table 13. Application of the template analysis: Technical factors

Code	Project	Evidence from interviews
COMP.SOL	Project 8	"The testing phase was delayed because of technical complexity of the phase"
SYST.INT	Project 1	"in the middle of the way we were told that another system for product life cycle management was being implemented at the same time and our project should have been integrated with it"
ERP.CUSTOM	Project 1 Project 9	"There were also some peculiarities in the client' processes, and nobody told the consultants about it" "We made some functional mistakes, because did not know that some processes in the plant could not be accommodated in SAP"
BPR	Project 3	"The business processes description was done with a very low quality [by a partner company]"
LEG.SYST	Project 6	"And there were as usually a lot of duplicates in legacy systems, e.g. material – nail, in one case will be written as "nail, 12 cm", in the other "12 cm, nail"... So you need to match all entries to make them unique. Finally this really painstaking task was done by the consultants and that took a lot of time and caused delay"

Management and communication factors

Management and communication reasons were found to be the most common reasons for delay and played an important role in eight out of nine considered projects. The most recurring problem though was the inappropriate organization of internal client's team work. The deeper reasons behind such organization are considered to be the lack of motivation and the difference in perception of project by consulting company and client. However, the stated reasons can be biased due to their subjective nature. One of the arguments in favor of a more balanced position is that the report of the Project Performance Audit organized by a vendor of ERP-system stated that consultants did not communicate well with the business representatives and even behaved arrogantly. At the same time, it is still a very important 'snapshot' of the subjective reality of project participants. In addition to that, inappropriate communication was identified as another important problem, which stemmed from a variety of sources including unclear division of responsibilities, working through mediators, complicated hierarchical structure and infrastructural limitations. The result of the application of template analysis to the project data regarding management and communication is presented in Table 14.

Table 14. Application of the template analysis: Management and communication factors

Code	Project	Evidence from interviews
PLAN.MAN.	Project 6	"There was no clear task set with a timeline, during certain project phase to ensure data migration (within client team). It was not clear who should do this."
	Project 5	"Work from the client's side was not organized"
	Project 1	"Databases were not filled on time, especially specifications of the products (aircrafts). Only one person was assigned to this task, scheduled at 50% of working time … the overtime work was not organized"
	Project 9	"Bad organization of internal team. Sometimes PM from the team side was programming himself to transform an old database to the required format. No separate group for filling databases"
	Project 3	"PM from the client's side did not have enough skills to implement the project"
	Project 8	"… the testing team was organized inappropriately"
	Project 9	"Key users were supposed to spend 30-50% of their time on the project, but in fact it was 5-10%."
CONTROL	Project 3	"The initial part of the project executed by the partner company took too much time"
	Project 9	"databases/reference books was a major issue since there are dozens of thousands entries. And they should be filled according to certain standards… but [it] was not ready on time"
INVISIBL.		
TRAINING	Project 9	"Low level of pre-implementation automation of the plant and computer literacy of the future users"
COMMUN.	Project 1	"There was no dedicated PM from the client side in the beginning. Only after a year she was appointed, before they had to work via the partners (business consulting company) and that was not efficient ("Chinese whispers")"
	Project 7	"It is very difficult to inform all participants ... You can send them emails, but you cannot guarantee that they will read it, … understand it correctly, …do what you want and when you want"

	Project 2 Project 8	"So we didn't have access to their systems and they did not have access to 'sandbox'. This work organization caused serious delays" "It was not clear who was a supervisor in the integrators' teams, who is responsible for some parts."
PROJ.MAN.	Project 7	"the people who planned (PMO) did not take everything into account… ['blue print' paper] was planned to be finished in two months, but it was clearly not enough, in fact 4 months were required"
WORK.COND.	Project 1	"First we sat with the company staff and later were given a tiny room for the whole team. For the first two months occasionally there were problems with electricity and Internet"

Goals and scope setting factors

The goals and scope setting factors represent an important subset of delay reasons. The complete data that emerged from the template analysis is depicted in Table 15. The most momentous reason in terms of rate of occurrence was 'oversale' and was met in nearly half of the projects considered. The 'oversale' was either in terms of tight project duration or broad scope. It stemmed from two main sources, namely the difference in perceptions of proposal team and project execution team and also from severe financial needs of a consulting company, which was pressurized to win the bid by any means. The overall characteristic of the category is that although the reasons indicated here are not as widespread as the management and communication reasons discussed in the previous subsection, nevertheless they usually cause most severe consequences. For example, the initial wrong strategic decision in Project 4 to unify business processes and subsequent change to more customized approach made many conceptual phase results obsolete and the completion date was postponed three times.

Table 15. Application of the template analysis: Goals and scope setting factors

Code	Project	Evidence from interviews
CHANGE	Project 5 Project 1 Project 4	"First they wanted to merge the company with another one (which had completely different business model, i.e. included logistics) but later cancelled the process, although a lot of effort and time was devoted to it" "During the project the client company owner has changed … the new owners demanded to run the 'production start' for other product group. So… the time was spent pointlessly." "finally we had 30 000 man hours of tailored development plus writing interfaces with legacy systems which completely contradicted initial unification plan and thus caused delay"
MISFIT	Project 5 Project 4	"High dynamics of business vs SAP requirements for stable processes", "Unclear 'to be' model vs one 'to be' model required in SAP", "Small size (30 users) vs SAP advantages for big systems (>200 users) – it's a problem since there are not enough people to enter and control detailed data in the system" "The client was not prepared for such a large scale project, especially to the implementation of all-new "to be" processes based on best practices"
STR.DECIS.	Project 9	"The client has a wrong idea about capabilities of SAP solution. They required to use standard SAP functions (to avoid additional

	Project 4	costs related to tailored development), although it was not possible" "they developed the conception "80/20" – 80% of SAP standard, 20% of the tailored development. It was impossible to do because of different business directions… we were forced to write "to be" solution without the analysis of "as is" situation … They took as a template the solution previously implemented for mining division, but it was not suitable at all for different businesses"
INV.EVAL.		
ERP.SELECT.		
OVERSALE	Project 5 Project 1 Project 2 Project 8	"Also our mistake – 'oversale'. If you write in the contract more than you can do, there always will be a person who will point it out" "It is not clear why our executives agreed on 9 months duration, it was clear that it is impossible to deliver the result during this period" "this project was sold by a manager who did not understand the specifics. So the duration was severely underestimated" "In fact, the conceptual phase has lasted for 6 months instead of 7 weeks. The scope of work was underestimated."
CONTRACT	Project 5	"many contract clauses could be interpreted differently and additional work emerged"

Socio-political or 'soft' factors

The socio-political or people-related factors represent other important and often underestimated subsets of reasons for project delay (Baraldi, 2009, p. 20). These factors along with the relevant excerpts from the interviews' transcripts are presented in Table 16, similarly to the previous subsections. There are two main reasons for delay in this category. The first one is related to the lack of political support, both from the consulting company's senior executives and, even more importantly, from client's top-management. The second reason, strongly related to the first one is the lack of involvement of business representatives, e.g. the future system users.

Table 16. Application of the template analysis: Socio-political or 'soft' factors

Code	Project	Evidence from interviews
CLIENT.SUP.	Project 1 Project 9	"It was not clear who actually ordered the project. The CEO was not interested, future users were not interested and so on", "Technical director of the company negotiated with the CEO and finally ensured that his subordinates will not participate in the project" "Their PM was not very motivated and / or did not have enough resources"
PEOPLE		
MNGMT.SUP.	Project 9 Project 4	"Too late started to involve project sponsors" "Where was no support from project sponsors and executives to argue with business"
USER.ACCEPT.		
CULTURE	Project 4	"[PM] did not know Russian language, and of course all internal company documentation was in Russian. … there were also communication problems with Indian subcontractors, they cannot admit that they don't know something"

	Project 3	"The [client] head office misunderstood the cultural environment of the local branch"
INVOLV.	Project 1	"Level of motivation was fantastically low.", "They were trying to avoid responsibility this way, didn't want to think on their own."
	Project 9	"There was only a limited involvement of business representatives in the project"
	Project 5	"Business [future users] did not participate, started to participate only closer to the end of project, this brought reworks"

4.4. Complexity categories

In order to identify the complexity elements that were present in the investigated projects and to see whether they occurred in singular or multiple cases, the data collected from the interviews has been divided according to the complexity codes aforementioned in the revised template. Hence, for each complexity code, for each project, where it was applicable, the relevant excerpts from the transcripts were extracted. Therefore, in order to have a clear picture, this information has been compiled into four tables, according to the main complexity classes: *Structural complexity, Uncertainty, Perceived complexity* and *Dynamic complexity* (Appendix 1). However, only in very few cases it was a clear match between the interview excerpt and the complexity code. More often it was difficult to establish which codes describe best certain information from the transcripts. Thus, the categorization process is based on researchers' understanding and analysis of the meanings and implications behind the interviewees' answers. Therefore, there might be other complexity elements that characterized the projects than the ones identified, for which there was no clear evidence in the collected data.

Structural complexity

Considering the most popular project dimensions in the literature, the elements of structural complexity have been grouped into technological, organizational and contextual. According to Baccarini (1996, pp. 202-203), the technological complexity refers to the transformation process that converts inputs into outputs, involving the utilization of material means, techniques, knowledge and skills. On the other hand, the organizational complexity refers to the functions of a project organizational structure such as "definition of relationships in terms of communication and reporting; allocation of responsibility and authority for decision making; allocation of tasks" (ibid). In the contextual complexity subcategory, the remaining complexity elements have been grouped, that mainly refer to the general setting in which the project is executed and the project constraints.

As it can be seen in Table 1 from Appendix 2, almost half of the analyzed projects are large scale, involving big teams and high number of processes with various peculiarities, which often imply a wide scope.

The main technological complexity stemmed from the data misfit and the lack of technological integration. However, as in most of the cases, this was closely related to other complexity elements. For example, in Project 1, the integration problem stemmed from a concurrent project on another IT system implementation that has to work in harmony with the ERP system in question. On the other hand, in Project 2, the lack of technological integration led to communication problems within the team, between consultants and programmers. Nonetheless, another technological complexity element that occurred in projects, although it did not necessarily had implications on other elements, is the complexity of the existing IT infrastructure of the client. Thus, according to the interviewee in Project 4 the interviewee stated “the existing system which was used for payroll accounting was interrelated with 148 other systems” while in Project 8 it was stated that “there was a complex IT infrastructure”. Furthermore, Project 1, Project 4 and Project 5 required a high degree of customization due to variety and specifications of business processes.

On the organizational side, the main recurrent issue seemed to be the lack of human resources from the client side. However, behind this complexity factor lie other elements, such as the socio-political games in the project, stakeholders’ level of motivation and commitment, as well as various changes of stakeholders. In Project 1, the insufficiency of human resources occurred at multiple levels. Firstly, for one year there was no project manager assigned from the client side which led to an inefficient communication, as the consultants had to work via partners. Second, there was only one person assigned to fill in the database, which would allocate 50% of the work time for the task, although this errand was supposed to be done by the product/process engineers. This was a consequence of internal political games and lack of top management support, as the technical director negotiated with the CEO for his team not to be involved in the projects. Furthermore, the lack of interest in the project from the senior management resulted from the several changes of the client company owners that occurred during the project lifecycle. With every change, consultants needed to “sell” the project again. On the other hand, in Project 4, the main reason for the lack of participation of certain teams was the low level of motivation. In this respect, the accounting team did not participate at all, as their manager announced major downsizing, which inevitably demotivated employees. Furthermore, in Project 5, the low availability of key users was a consequence of their lack of involvement due to competing priorities, as they regarded the project to be secondary to their departmental activities and thus dedicated only 5-10% of their time instead of the staffed 30-50%.

Among the elements of contextual complexity that stand out is the multiculturalism of the project team and stakeholders. In this respect, in Project 3 arose cultural clashes, as the client head office misunderstood the cultural environment of the local branch. On the other hand, in Project 4, it led to communication problems, as the assigned project manager from the consulting side was Brazilian and did not know Russian language, which proved to be an issue as all project documentation was in Russian.

Uncertainty

In the uncertainty category only the elements related to the lack of knowledge and experience of stakeholders were identified, leading to the subsequent lack of clarity and information (Appendix 2 – Table 2). Given the nature of the ERP system implementation projects, the technological breakthrough development is unlikely to be met, since the projects are based on already known and existing technologies. Thus the element of novelty is related to the degree of customization, the stakeholders' previous experience with such specifications and their level of knowledge and competences.

As it was emphasized by the interviewees, the element of novelty is inevitable in the ERP implementation projects because each project is unique and each setting has its own particularities and thus there is always a lack of knowledge and experience. First, in three of the analyzed projects, project managers did not have the required experience or set of competences. In Project 9, the project manager from the consultant company had less than 2 years of experience, while in Project 3 and Project 4 the project manager from the client's side lacked experience with the ERP systems and did not have the necessary skills to successfully implement the project. Furthermore, in almost all projects, consultants were confronted with a lack of competences from the client's side or from the subcontractors' side. Therefore, in Project 1 and Project 5 the team members from the client company did not know the systems in place, while in Project 8 there was a lack of technical specialists in the team from the client's side. In Project 2 and Project 4, the company worked with subcontractors who not only did not have enough competences, but also would not ask for help when they were unable to fulfill the required tasks. Moreover, in Project 7 the business representatives did not have any experience with the ERP system, while in Project 9, the future users lacked basic skills such as computer literacy.

Another recurrent uncertainty element was the ambiguity of goals and requirements. The lack of clarity was brought by various sources in different projects such as: client's lack of strategic direction (Project 1); lack of objectives and requirements formalization (Project 4; Project 7) and ambiguous contractual clauses (Project 5).

Furthermore, this was complemented by a limited data availability due to lack of processes documentation, which was further amplified by a lack of communication. In two of the projects, several peculiarities in client's processes were discovered towards the end of the projects lifecycle, as no one from the client organization informed consultants about them (Project 1; Project 9). Moreover, in Project 9, the lack of communication was a consequence of stakeholders' lack of involvement and commitment towards the project.

Perceived complexity

Three main categories were identified under the perceived complexity: common understanding, socio-political games and emotional aspects (Appendix 2 – Table 3). However, the complexity elements of these categories are highly interrelated. It seems that misunderstanding of project implications and responsibilities were common characteristics for most of the projects and created further complexity. On one hand, in Project 4 and Project 9, stakeholders' wrong apprehension in regards to the ERP systems led to several wrong managerial decisions and to formulation of inappropriate requirements that ultimately had to be changed. On the other hand, the misunderstanding of system's specifications in Project 2 led to wrong estimations of deadlines, creating unrealistic expectations. However, in Project 1 and Project 5 these unrealistic expectations were a consequence of unfeasible performance estimations made by the consulting companies in the bidding phase. Furthermore, in Project 9, the lack of a full understanding regarding the project's implications led to a lack of involvement as stakeholders undermined its importance. However, one of the most frequent elements that emerged from the data, being mentioned in almost all projects is stakeholders' lack of commitment. Often the lack of involvement is strongly related to the general lack of motivation that can emerge from a variety of reasons: stakeholders are not affected by the outcome of the project (Project 4), as it was the case of the consulting company partner who would return to his home country in a couple of months or the change management group that was not evaluated on the basis of their contribution to the project; the outcome of the project has a negative impact on stakeholders, as it was the case of the accountants that would lose their job as a consequence of the ERP implementation (Project 4); low financial rewards as it was in the case of the subcontracted programmers (Project 2). In addition to that, in some cases the lack of stakeholders' commitment came as a result of the inherent resistance to change (Project 4) or political games and personal interests (Project 3). However, it is interesting to note that in Project1 and Project 9, the financial motivation of some employees led to additional quarrels in the project team and disputes on equity of the benefits distribution.

Dynamic complexity

Four subcategories of dynamic complexity emerged from the data analysis process. The relevant transcripts excerpts associated with each subcategory have been presented in Table 4 from Appendix 2. Out of these complexity elements, the change in requirements seemed to be the most significant one as it was clearly emphasized by respondents and it occurred most often. However, it is interesting to note that in every single case the change in requirements was caused by one or more static complexity elements or by other dynamic complexity elements. In Project 4, the change in requirements was triggered by the client's misunderstanding regarding the implications of the project, which led to a series of bad managerial decisions. In Project 1, the root of the change in requirements lied in the change of project sponsors, as new sponsors came with a different vision and new demands, ignoring what was established in the beginning of the project. In Project 5 it was a mix of complexity elements that led to changes. First, there was a change in client's strategy: initially it wanted to merge with another company, but later it decided not to, affecting the scope of the project. This was possible as on one hand the contractual clauses were ambiguous, allowing multiple interpretations and on the other hand because the consultants were pressured by their superiors to accept any change in scope, in order to ensure future collaboration of the company with the client.

4.5. Connection between categories of complexities and reasons for delay

Table 1 from Appendix 3 aims to depict the linkages between the reasons for delay and the complexity categories for each project. Thus, the first column depicts the reasons for delay considered by interviewees to be the most crucial, coded according to the corresponding template. The second column contains the corresponding complexity codes that were identified across projects as the transcripts were scrutinized. Finally, in the last column, it was explained how the complexity elements that characterized the projects contributed to the overall delay.

The "Systems to be replaced, data misfit, technical and infrastructural integration" complexity category recurred most often in relation to the identified reasons for delay. Thus the lack of technical and infrastructural integration underpinned the inappropriate integration of systems and the technical complexity of the developed solution, which subsequently brought on additional work, causing delays in Project 1 and Project 8. Furthermore, in Project 6, the neglect of legacy systems, that were characterized by data misfit due to various entries for a single item led to a significant amount of work that generated delays. In Project 2 the lack of technical integration led to an inappropriate communication as the consultants had to spend a lot of time on making print screens and writing explanations, which were not fully understood by the programmers and thus the developed solutions needed rework. Furthermore, another element of structural technological complexity that was connected to various reasons of delay was the business processes' complexity, which contributed in Project 5 to the misfit between business requirements and the system functionality and in Project 1 to an eventual inappropriate customization of the ERP system.

The organizational complexity also played an important role through its various categories. The most important issue seems to be the inappropriate allocation of resources that led to poor planning and management (Project 1; Project 9) and further to losing control over the implementation (Project 9) as the tasks were not completed on time. Furthermore, in Project 7, the complex approval processes generated communication problems and delayed the starting time of several activities.

The contextual complexity was mainly represented by time pressure and it was rather a consequence of project duration underestimation, which in some cases was intended, as the consulting companies were interested in winning the bids (Project 1; Project 5), while in other cases it was simply a result of specifications misunderstanding or lack of competences (Project 2; Project 8). In addition to that, in Project 1, the client's failure to accommodate the team with suitable facilities led to inappropriate working conditions.

As it was stated by the interviewees, every project brings something new as it has its own particularities. Therefore, uncertainty played an important role in the project overruns. In Project 9, the elements of novelty and the lack of experience of project managers led to an inappropriate ERP customization, while in Project 3, the lack of competences of the project manager from the client's side led to poor planning and management. Furthermore, in Project 9, consultants had to spend extra time on user training as the employees lacked basic competences, such as computer literacy. In addition to that, in Project 5 the contract was ambiguous as several clauses were subject to multiple interpretations.

In Project 4, stakeholders' misunderstanding of the project's implication was crucial as it led to a set of inappropriate strategic decisions, which further induced a change in the business goals during the implementation and thus in project's requirements. On the other hand, the lack of clarity in the line of responsibility for tasks and deliverables created problems in the communication process in Project 8 and led to poor management of the data migration process in Project 5.

The project complexity generated by the socio-political games present in the clients' organizations also had a strong influence on the project delay, especially through the lack of stakeholders' commitment and involvement, which was sustained by the lack of top management support in Project 4 and Project 9. However, both stem from the lack of motivation, a complexity category related to the emotional aspects. This was mainly translated into a lack of availability of human resources for the projects which made the initial planning inappropriate. Nonetheless, in Project 3, the conflicts, power struggles and hidden agendas between stakeholders also contributed to the delays, leading to inappropriate process reengineering activities and eventually to the loss of control over the implementation.

The most important aspect of dynamic complexity was the change in requirements, which usually generated significant amounts of additional work, thus contributing directly to delays. In Project 1, the change in business goals and subsequently in the project scope was actually triggered by another dynamic complexity, the change in project sponsors, as new persons would came with new vision and new requirements.

4.6. Questionnaire analysis and data triangulation

The questionnaire responses presented in the Appendix 4 generally reinforced the findings from the interviews. In this respect, the overall lack of experience, knowledge and managerial competences were rated to have the highest impact on projects' delays. Furthermore, among the complexity elements that were considered to have a high influence, the availability of human resources, the tight time constraints and the lack of commitment and support from stakeholders were identified. The technological complexity, represented mainly by the number, variety and integration of IT systems and business processes was considered to have a significant impact only in certain projects. On the other hand, several contextual elements lay at the opposite pole, such as multiple time zones, variety of cultures and languages and strategic alignments of project's objectives were either not present in several projects or were deemed to have a low impact on projects' delays. In addition to that, more elements of structural complexity were considered to play a less important role such as the high number of concurrent projects and the implicit shared resources and the number of specializations and roles involved in the team.

Thus in accordance with the findings from the semi-structured interviews the questionnaire results revealed that the uncertainty plays an important role in projects' delay. While the availability of human resources was rated high, it was shown in the previous subsection that in most of the cases it was a consequence of perceived complexity elements such as socio-political games and stakeholders' level of motivation and commitment. As well, the high time constraints were shown to be either a consequence of project duration underestimation, due to misunderstanding of specifications, or a consequence of management's pressure to tighten deadlines, in order to win bids. Therefore, it can be concluded that the elements of perceived complexity brought a significant contribution to project delay. On the other hand, the complexity elements with the lowest ratings belonged to structural complexity, the majority of them having a contextual nature.

However, the questionnaire results also brought to surface complexity elements that were not emphasized in the interviews, such as personality clashes, which were explicitly mentioned only by one participant, in regards to Project 9.

4.7. Summary

Overall, the data analysis process reinforced the reasons for delays and complexity categories identified in the literature and in the same time brought to surface new information, as new codes emerged and the initial templates were modified. For each project multiple reasons for delay and multiple complexity categories were identified. Nonetheless, the categorization process proved to be not straightforward as in most of the cases it was not a doubtless match between the transcripts excerpts and the codes. Therefore, it is possible for some categories to have been present in the project but to be overlooked as they could not be deducted from the gathered data. However, this limitation was overcome to a certain extent through data triangulation, as new information emerged from the questionnaires, completing the data from the interviews. Thus, one of the main findings that emerged from the questionnaire is that almost all complexity categories were present in the projects, which support the holistic view on complexity adopted in the recent literature.

As it can be seen from the analysis on complexity categories, there are strong interconnections between various complexity elements. In most of the cases, it was a chain reaction effect, as one complexity element triggered other elements. However, in some cases there is not one complexity element but a mix of elements that create further complexity. One example among the many provided is that the change in requirements in Project 4 was generated by stakeholders' misunderstanding of the project implications, corroborated with the lack of management support in arguing with the wrong managerial decisions, in the context of complex business processes. Furthermore, an analysis of the identified complexity categories showed that some categories occur more often than others. Thus, most projects were characterized by the following complexity categories: “Systems to be replaced, data misfit, technical and infrastructural integration”, “The client and supplier accommodate project well”, “Stakeholders’ knowledge and experience”, “Implications of the project are well understood”, “The line of responsibility for tasks and deliverables is clear in the client's organization”, “Stakeholders’ commitment and involvement” and “Communication”. However, overall the structural complexity does not appear as often as the uncertainty, perceived complexity and dynamic complexity and it rather plays a magnifying role for the latter ones.

When the two sets of data were analyzed in parallel, the strong relationship between the reasons for delay and the complexity categories was revealed. On one hand, for the most reasons for delay, more than one complexity categories were identified to have contributed to it. It is also interesting to note, that the same reason of delay was caused by different complexity categories in different projects. For example, the inappropriate implementation of ERP system was caused in Project 1 by the mix of complex business processes, inappropriate communication and lack of data availability, while in Project 9 it was generated by the lack of experience of project managers and the novelty of certain functions for the consulting company. On the other hand, same complexity category can contribute to various reasons for delay. For example, the misunderstanding of project implications led to change in requirements in Project 4, to inappropriate strategic decisions in Project 9, to underestimation of project duration and thus overselling in Project 2.

Overall, the factors that seemed to have the highest impact on project delay were the organizational inefficiency that was underpinned by the inappropriate human resource allocation from the client side and its availability and the lack of client’s organizational maturity in terms of operations, risk management and change implementation. On top of that, this often happened in the context of a general lack of motivation that led to low commitment and involvement of stakeholders, which was actually the main cause of low level of participation and subsequent weak performance of client employees. Furthermore, as each project represented a unique endeavor, bringing a set of novelty elements for the project team, it led to an inherent lack of experience and knowledge, which corroborated with the stakeholders lack of competences generated project delays through inappropriate customization, poor management and deadlines underestimation.

In the following chapter the chapter findings will be compared with the existing studies and subsequently a conceptual theory will be suggested that would explain the results of the present research with aid of visual representation.

CHAPTER 5 - DISCUSSION

The present chapter presents a discussion of the research findings from *Chapter 4 - Data Analysis*. It is particularly important since the data analysis chapter did not allow us to determine a simple and straightforward answer to the research question. This corresponds to the inductive and qualitative nature of the study, which aims to conclude building-up a theory instead of confirming or refuting a predefined theory.

The chapter is structured as follows. Firstly, the findings derived from the data analysis are discussed in comparison with other publications on the topic. This part is structured in sections according to the main categories used for the data analysis, i.e. reasons for delay, complexity dimensions and the relationship between them. Particular attention is paid to any discrepancies found. Although the findings represent the "raison d'etre" of the study, they are complemented with the development of a theory in the last section. This aims to build a conceptual model upon the findings, which will provide a visual representation of the phenomenon in question. It should be explicitly stated that the theory is derived by analytical inference (Yin, 1989, p. 38) and thus is not 'proven' in a statistical sense, representing rather a hypothesis to be studied in the future.

5.1. Reasons for delay

There is a vast body of publications on reasons for delay in different industries and contexts, for instance construction and engineering projects (Al-Momani, 2000; Eden et al., 2005; Toor & Ogunlana, 2008), public projects (Arditi et al., 1985), defence projects, IT projects (Venugopal, 2005), ERP system implementation projects (Sanchez et al., 2010; Ehie & Madsen, 2005; Kumar et al., 2003; Baraldi, 2009; Soja, 2008b; Xue et al., 2005), software development projects (Van Genuchten, 1991) to name a few. Moreover, the studies on project delays are often carried out in one country. For example, the mentioned Arditi et al. (1985) study was done in Turkey, Toor & Ogunlana (2008) - in Thailand, Soja (2008b) – in Poland, Baraldi (2009) – in Sweden, Xue et al. (2005) – in China, Kumar et al. (2003) – in Canada. The very existence of such focused studies along with a lack of a broader research on the topic indicates that the findings on reasons for delay may be context specific.

Therefore, in the present discussion we have decided to concentrate specifically on studies devoted to reasons for delay in ERP system implementation projects. Regarding the reasons for delay, the following research findings were identified in the study and need to be compared with the literature:

- The range of reasons for delay encountered in the cases studied was very broad, with the majority of reasons from the corresponding template met at least once and all groups of reasons being represented
- There were more than one reason for delay in all cases
- The most common reasons for delay with the strongest influence were found to be 'lack of client involvement', 'inappropriate organization of client's

employees’ and ‘lack of motivation’ which is surprising given the technical complexity of the ERP-systems

- Several new reasons were identified in comparison to the initial template

The broad list of possible reasons for delay identified in our study and the fact that the same set of factors was not met twice corresponds to a wide list of factors identified in different studies (Basoglu et al., 2007, pp. 79-80). Since the initial template was found suitable to describe reasons for delay in our cases, the encountered set of factors is overall in agreement with the existing literature. Furthermore, the finding that reasons do not come alone is in line with the article of Xue et al. (2005), where in each of the five case studies were identified two to five major reasons for failure. Moreover, considering that in the latter study the reasons were aggregated (e.g. Business Processes Reengineering reason included organizational change issues), it can be assumed that with our level of decomposition there would be even more reasons for each case.

However, several new factors were identified in the present research, in comparison with the initial template based on the Basoglu et al. (2007) review, i.e. ambiguity of contract clauses, inappropriate working conditions, ‘oversale’ and lack of client’s staff motivation and involvement. The importance of the ‘soft’ issues found in the study is not surprising if ERP systems implementation projects are considered from the organizational change perspective (Kerimoglu et al., 2008, p. 23; Soja, 2008a, p. 106), requiring changes in the way people work. Furthermore, it should be mentioned that it is difficult to delineate the distinction between reasons for delay as the terminology, the levels of decomposition and the perspectives used to classify factors vary from publication to publication. Thus, it is impossible to claim the novelty of the reasons identified. For instance, ‘oversale’, the reason often mentioned in the interviews, is strongly related to the underestimation of project risks, stressed by Soja (2008a), as well as to the different perceptions of sales and project teams.

Different authors underline different possible causes of delay (Baraldi, 2009, p. 26), many of which were met in our case studies. For example, the technical complexity and the misfit between business requirements and the system functionality suggested by Davenport (1998) and the inappropriate strategic decisions (e.g. on BPR) underlined by Buckhout et al. (1999) are all found to play an important role. Nevertheless, in our study ‘soft’ factors, especially related to motivation and involvement of team members from client side were found to be the most pertinent ones. This corresponds to the research of Baraldi (2009), which showed the importance of the user-related perspective and the misfit in perceptions to be important reasons for delay (p. 41). Overall the ‘soft’ reasons typically correspond to the overlooking of the people dimension (Basoglu et al., 2007, p. 79). Furthermore, the communication issues within the consultant team, as well as with the client are in line with the findings of Venugopal (2005). These issues correspond to the very nature of ERP implementations, since ERP systems affect all functions existing in the organization (Kerimoglu et al., 2008, p. 26). Finally, the pronounced ‘oversale’ factors refer to the lack of knowledge and the risks misperception of the project sales team (Soja, 2008a).

At the same time, some researchers reached different conclusions. For instance, Xue et al. (2005) offered a model of eight implementation failure factors, classified in two major categories (environment and culture) that influenced technological issues and thus led to implementation failure. It can be noted that only two factors out of eight were identified to be important in our study, i.e. Business Processes Reengineering (BPR) and human resources (although this factor was understood very broadly and included lack of top management support, incompetence of project team and unrealistic expectations). Other factors were either not encountered, for example the difficulties of precise translation into the local language (Chinese in case of Xue et al., 2005), or were less important in the cases studied, for example, the misfit between culturally-embedded ways of doing business and ERP capabilities. This divergence in research findings underlines the importance of the context mentioned above, in this case showing the peculiarities of ERP implementation projects in China.

5.2. Complexity categories

There are several research findings regarding the complexity dimensions that need to be compared with the literature:

- All major complexity categories were found in the study
- Uncertainty, Subjective and Dynamic complexity appear more often than Structural complexity
- Different complexity categories (and factors) are interrelated entities

Traditionally, the complexity of ERP system implementation projects was considered from the Complex Products and Systems (CoPS) perspective (Hobday, 1998), in consistence with the structural dimension (Baccarini, 1996). However, in the view that complexity is a characteristic that makes difficult the prediction of system's behaviour, such perspective is limited (Baraldi, 2009, p. 37). For example, some projects analyzed in our study are relatively simple from the technical point of view and considering the number of future users involved (system size), but they are not predictable due to other dimensions (i.e. Project 5). This example underlines the importance of the holistic view of complexity (Geraldi & Adlbrecht, 2007, p. 32), since the project would not be classified as complex, without the concomitant presence of dynamic and ambiguity dimensions.

As a response to the limitations of the structural dimension of complexity, there is an emerging trend of studying the 'soft' perspective (Baraldi, 2009, p. 20), particularly in the literature on ERP systems' adoption (Kerimoglu et al., 2008). This perspective is related to uncertainty (in terms of lack of knowledge) and subjective or perceived dimensions. Recently, Müller et al. (2011) have empirically validated a more holistic framework, comprising the complexity of fact (similar to structural), complexity of faith (similar to uncertainty) and complexity of interaction (similar to subjective) in a study where the majority of projects were IT-related. Our findings support the emerging trend of the importance of the uncertainty and subjective dimensions, but also underline the importance of dynamic dimension. As far as the structural (mainly technical) dimension is concerned, it appeared in the study that it plays the role of an amplifying factor and it is mainly the imperfect knowledge and communication in regards to the technical complexity that hinders predictability, not the structural complexity in itself.

The complexity dimension that is largely overlooked in the literature regarding ERP system implementation projects is the dynamic one. However, it was shown in the study that this dimension plays an important role and should not be overlooked. This is in accordance with the wider literature on IT projects, since the change in business goals during the implementation (an element of dynamic complexity) was found to be among top three reasons for IT-projects failures (Wilder & Davis, 1998, cited in Basoglu et al., 2007, p. 74).

It was also found in the study that various complexity dimensions are strongly interrelated, a fact to which it was not paid enough attention in the literature, with the notable exceptions of Williams (2005, pp. 499-500, 503) and Müller et al. (2011), who stated that "intuition might even suggest that coexistence of different types of complexity may intensify the overall intensity of complexity" (p. 4). In the literature on ERP implementation projects, this corresponds to the assertion that "it is difficult to delineate a separating line between ERP and context" (Xue et al., 2005, p. 286) and technical, cultural and environmental factors are interrelated (ibid, p. 292). However, the authors did not relate their findings to the complexity concept.

5.3. Relationship between delay and complexity categories

There are several research findings regarding the influence of complexity dimensions on project delay that need to be discussed in this subsection:

- In all cases studied, the delay was related to one or (more often) several complexity categories
- Subjective, Uncertainty and Dynamic categories influenced delay more often and more profoundly than Structural complexity
- The interplay between complexity and delay is an intricate one, most of the reasons for delay being underpinned by diverse complexity measures, showing that there is no univocal correspondence between them

As it was stated in the literature review, there is a lack of studies regarding the connection between project complexity and delay. Hence, there are not many references to compare our findings with. Consequently, articles within broader research field of project complexity and project success were brought into discussion.

Based on the analysis of the case studies, we put forward the proposition that project complexity always underpins delay, since all delayed project considered in the study were complex from certain perspectives. Therefore, the surface 'reasons for delay' can be merely a manifestation of a deeper phenomenon, i.e. project complexity. Specifically, this can be the case for delays exceeding contingency limits that indicate 'natural' or expected variability of completion date. Furthermore, the finding that there is no univocal correspondence between project complexity measures and the reasons for delay is somewhat new and was not encountered in the literature.

It was found in the study that the subjective dimension plays crucial role in relation to delay. This is in line with Baraldi's (2009) article, where he has identified that the user-related dimensions of complexity, e.g. users' perception of ERP system complexity, played the most important role in project delay. Although the cited study was the only study focused on the relationship between complexity and delay in ERP system implementation projects that was identified in the literature review, some insights can be also obtained from other related works. For instance, albeit Eden et al. (2005) studied cost overruns, considering mainly labour cost expressed in labour hours. Thus the study is closely related to delays and notions of delay do appear in discussion. However, the cases used in their study are taken solely from the engineering & construction domain. In addition, the perspective taken was not that of the complexity measures lens, even though many different complexity measures appeared in discussion. Nevertheless, the authors claim that "labour costs overrun significantly more than can satisfactorily or easily be explained. Non-labor costs can more usually be tied to specific causes" (Eden et al., 2005, p. 16). This means that the number of labour hours required is more difficult to predict and it may refer to the pronounced subjective and uncertainty-related dimensions. Thus, underestimation of the subjective dimension of complexity in prior research (e.g. based on Baccarini, 1996), hindered the progress in the explanation of project delays.

Accordingly, the theoretical predictions of probabilities and the extent of project delays obtained by the operational research methods (e.g. Tavares et al., 1999; 2004) are unlikely to explain and predict real life project delays. The main reason for this is that the morphological network complexity parameters used in the studies (which in fact represent a subset of structural complexity measures) do not capture the complexity dimensions identified as having significant influence on delays in our study. In addition to that, there are no studies testing the conclusions of Tavares (1999) on an empirical dataset of real projects.

Furthermore, the importance of the subjective/perceived complexity dimension is two-fold. First, this dimension is not typically revealed during bidding (and estimation) phase and thus cannot be included in the project plan. Second, this dimension is actively influencing other dimensions, making the system behaviour even less predictable. For example, lack of motivation of team members from client side ('subjective') may lead to lack of information for consultants regarding peculiar processes or legacy systems ('uncertainty'), which eventually cause reworks and thus project delay.

Since there is a lack of studies with a narrow focus on the topic, it was decided to enrich the discussion by incorporating research findings from related fields. Particularly, the findings of the study can be compared with studies on overall project success. Although the studies pose different research questions, several valuable associations may be drawn from them. Regarding structural complexity, several authors agree that it influences overall project duration. For instance, Griffin's (1997) study on new product development projects showed that products' technical complexity, expressed in a number of functions, increases the development duration (p. 32). Similarly, Meyer & Utterback (1995) found that integration complexity (number of technologies) extends development time (p. 302). However, it does not mean that such projects are more likely to be delayed (just that they last longer). Instead, as Tatikonda & Rosenthal (2000) found out "the aggregate project complexity dimension is not associated with poor achievement of the time-to-market objective" (p. 81). The same conclusion regarding lack of association between project complexity and project success measures (technical performance, cost, schedule, or overall results) was made by Larson & Gobeli (1989, p. 123). However, these results should be interpreted with caution, as the authors typically considered complexity in a very narrow sense, merely as a subset of structural complexity parameters. Nonetheless, the results are in agreement with the findings of the present study, as structural complexity was found to play a secondary role in delay explanation.

The same pattern applies to the discussion on the influence of technological novelty on project delay. Again, it was determined that novelty led to greater development times (Griffin, 1997, p. 31), although it was not associated with the overall project success (Tatikonda & Rosenthal, 2000, p. 81; Larson & Gobeli, 1989, p. 123). This corresponds to the findings of the present study, as technological novelty was not identified as a major issue; however, other related sub-dimensions of uncertainty played an important role.

As it is clear from the previous discussion, the studies incorporated a very narrow view on complexity. To the best of our knowledge the only notable exception is the work of Müller et al. (2011) who investigated moderating effect of major complexity categories (complexities of fact, faith and interaction) on influence between leadership competences of PMs and project success. It was found that complexity of interaction influences project success directly (statistically significant 'main effect'). This result corresponds to the finding of the present study that the subjective category plays the most important role in relation to delay. Furthermore, complexity of faith was found to have a moderating effect on the relationship between emotional and managerial competences and success, whereas complexity of fact was found to have a moderating effect on the relationship between managerial competences and success (ibid, p. 8). Two comments are required in respect to these findings. Firstly, it is difficult to compare directly the findings of the present study and the ones of Müller et al. (2011) since the first one is focused solely on time performance while the latter considers an integrated success measure. Secondly, unlike the present study, their work had a sample of generally successful projects (Müller et al., 2011, p. 7). Therefore it is potentially possible that in unsuccessful part of project spectrum, there would be a direct influence of e.g. complexity of faith on project success. For example, if a project is attaining a certain level of complexity, then it can be that it fails regardless of leadership competences, indicating direct relationship. Despite these comments, the overall conclusion is that the findings of the present study are in accordance with the mentioned work as both indicate the relationship between complexity and project success.

The discussion on different complexity dimensions and their influence on project delay is taken further in the following section. More specifically the major findings discussed above are to be combined in high-level conceptual model enhancing understanding of the topic.

5.4. Theory development: Amoebic model of risk for project delay

In addition to the findings discussed in the previous sections, the study aims to contribute to the research field with the development of a conceptual model of the relationship between project complexity and risk of delay. In order to achieve this goal, the current section starts with an identification and description of requirements for the perspective model, discusses suitability of existing project complexity models by contrasting the models in the literature and the issues identified in our study and, finally, elaborates on them in order to suggest the conceptual model.

5.4.1. Requirements for a project complexity model

In this subsection we briefly present the requirements of the model to be built. These consist of two parts, namely, the model should encompass the research findings of the study, discussed above, as well as to satisfy formal requirements for a model of a complex system existing in the literature.

The general requirements for a good project complexity model are summarized in the assertion that "good representations make the important things explicit, expose natural constraints to facilitate computation, are complete, are concise, are transparent to its users and suppress detail when it is not required" (Eppinger et al., 1992, cited in Vidal & Marle, 2008, p. 1105). An example of the project complexity model requirements (from both theoretical and user perspectives) is presented in Fig. 8.

Complexity theoretical requirements	User requirements
Size of the project system	Validity and reliability of the model
Variety of the project system	Intuitiveness and understandability of the model
Interactions and interdependencies within the system	Suppress unnecessary detail
Context and environment dependency of the project system	Completion and concision of the model
Uncertainties and change propagation as consequences of complexity	Computability of the model

Figure 8. Project complexity model requirements (Vidal & Marle, 2008, p. 1105)

Regarding the approach to build a new model, we believe that listing new complexity categories is not enough for two reasons. First, there is an additional requirement for the model arising from the research question of the study, i.e. it should build the linkage between project complexity and delay. Second, the approach would favour the reductionism approach that was actively criticized recently in relation to the complexity topic (Schlindwein & Ison, 2004, p. 28).

Furthermore, regarding the completion-concision trade-off mentioned in Fig. 8, it is important to keep in mind that "there is likely to be an optimal level of complexity for the project models (such as decompositions) used to manage the project" (Vidal et al., 2007, cited in Vidal & Marle, 2008, p. 1106). Given that the field is an emerging one, a high-level model with a low level of details is deemed to be appropriate for the study.

5.4.2. Examples of existing project complexity models

The common approach in the literature to complexity model design is concerned with the creation of a comprehensive list of complexity elements, divided in certain complexity categories (Bosch-Rekveldt et al., 2011; Vidal & Marle, 2008; Maylor et al., 2008). As an example, Vidal & Marle (2008, p. 1107) have recently suggested a complexity model called *ALOE* model, that comprises attributes, links, objects and events. The potential elements of the model for each of the categories mentioned are presented in Fig 9. Although it is stated in the article that the model "permits to describe any characteristic of project complexity" (ibid, p. 1107), it seems that there are several inherent limitations. For instance, it does not encompass explicitly two important dimensions, i.e. uncertainty and subjective dimensions, which were shown to have an important impact in the study. On the contrary, as it can be seen from Fig. 9, it concentrates predominantly on descriptive complexity. Although it could be argued that dynamics category is partly taken into account by the 'events' category, the pronounced events are assumed to be known, thus not all types of risks are accommodated (Wynne, 1992, cited in Williams, 1995, p. 24).

Attributes	Links	Objects	Events
Quality	Hierarchical link	Objective	Occurred event
Cost	Contribution link	Deliverable	Potential event
(Duration, start date)	Sequential link	Activity	
Advancement	Influence link	Resource	
Description	Exchange link	Other project within the firm	
Allocated resources			
Added value			

Figure 9. ALOE Model (Vidal & Marle, 2008, p. 1107)

Even though some of the models are more holistic in the sense of complexity categories covered (e.g. Geraldi et al., 2011), they do not fulfil all requirements for a complexity model presented in the previous subsection. Most notably, the models do not suit the findings of the study regarding the interrelations between different complexity categories, since they merely list the parameters without acknowledging explicitly their interdependence. Furthermore, the models are descriptive and do not aim to link the complexity to the project failure or success (in case of our study – in regard to time performance).

A model of amoebic growth of project costs

The model developed in the study was inspired by a metaphoric model of ‘amoebic growth’, introduced by Eden et al. (2005) to explain cost overruns in projects. Although the model is generic, the authors did state that “we are particularly interested in “complex” projects, ones in which project outcomes are difficult to predict, and even difficult to explain post-hoc.” (Eden et al., 2005, p. 16), thus their approach could be relevant for the study. The backbone of the approach is a graphical representation where a well-predictable project is represented by a circle, with costs of its different aspects indicated by radii and the total cost given by the area of the circle. Underlying the metaphoric character of the model the authors warn against treating the radii as a formal decomposition.

Having analyzed several case studies with the aid of the graphical representation, the authors state that “the growth in cost is “amoebic” in nature (e.g. see Fig. 10). In other words, at the end of a project, it is not easy to pin down what drove the total cost overrun” (ibid, p. 16). This corresponds to our findings that there is rarely a single reason for project delay and interviewees often mention that overruns were building up and it is impossible to trace specific causes.

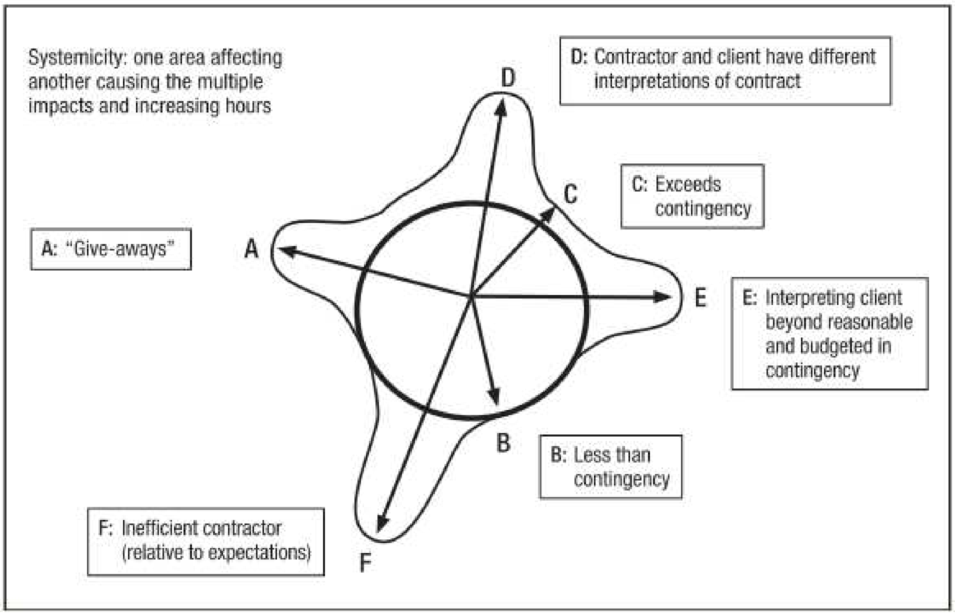

Figure 10. An example of Cost amoeba (from Eden et al., 2005, p. 22)

There are several comments on the amoebic model that should be made before proceeding to building the model in relation to delays. Firstly, the authors did not link the model of cost overruns to the project complexity, although all categories of the holistic perspective were touched upon in the article. However, as our findings indicate, there is strong relationship between complexity and delay, and the complexity seems to be a necessary condition for it. Secondly, albeit the author claimed that “often long and ramified causal chains need to be elaborated” (ibid, p. 24) to explain overruns, these are neither explicitly present nor obvious from the graphical representation used. Finally, the authors used PMI (2000) definition of a project as “a temporary endeavour undertaken to create a unique product or service" (Eden et al., 2005, p. 15). Arguably due to this somewhat limited perspective (Turner & Müller, 2003, p. 3) the choice of the case studies was restricted to large engineering projects. This narrow view of a project limits the application domain of the study, since, for instance, ERP system implementation projects are better described as organizational change initiatives (Soja, 2008a, p. 106; Basoglu et al., 2007, p. 74).

5.4.3. Development of a new conceptual project complexity model

Amoebic model of relationship between project complexity and risk of delay

In this subsection we suggest a high-level model, which fulfils the requirements discussed before. It generally follows the model of Eden et al. (2005) with a few notable exceptions. First, the model here is concerned with project delay, instead of the project cost overruns discussed in the article. Second, instead of circle radii representing "different aspect or arena of the project in some sense", in our case these will represent specifically project complexity dimensions and parameters to reflect the relationship found in the study. Third, by using a metaphoric representation of 'tangled strands' the interrelations of complexity dimensions and unpredictability of system are explicitly depicted in the model. The result of the 'amoebic growth' model adaptation to the research topic (including the model's link to the research findings) is presented below.

Link of the model to the research findings

The sub-section outlines the link of the model to the research findings discussed in the beginning of the chapter. The particular findings which were accommodated in the model are: (1) holistic complexity represents necessary condition for project delay beyond contingency limits; (2) all major complexity categories were found in the study; (3) different complexity categories (and factors) are interrelated entities; (4) in the majority of cases the delay was related to one or (more often) several complexity categories .

It can be seen that all suggested differences between the proposed model and the Eden et al. (2005) model correspond to the research findings of the study. At the same time, it has to be admitted, that the model does not encompass all the findings. Most notably, the model does not encompass the findings regarding frequency of appearance and depth of influence of the different complexity dimensions on project delay. It should be noted though, that the lower level of details could be appropriate for a complexity model (Vidal & Marle, 2008, p. 1106), especially for a visual model.

The model description

Following Eden et al. (2005, let a well-behaved project be represented as a circle, where all radii indicate influence of different complexity dimensions on the project duration and the area of the circle represents the total project duration (see internal circle in Fig 11.).

At the time of establishing the project plan this is how the project is supposed to behave. In fact, this expectation reflects not the project itself but rather an initial perception of the project by a project manager. Since perception is a process of cutting outside world according to certain individual cognitive patterns or filters (Jaafari, 2003, p. 49), the resulting perceptional model is naturally non-holistic since inevitably some elements or linkages are omitted. However, for complex projects such omissions due to interconnectedness of complexity dimensions result in unexpected consequences. Thus, if due to a number of possible reasons (initial misperception, unexpected events etc.) a single radius A is 'pulled' beyond the initial circle, this affects also all others tangled with it, e.g. B and C (see Fig.11), thus causing effect beyond what was expected. The interconnectedness is visualised with the aid of 'tangled strands' representation.

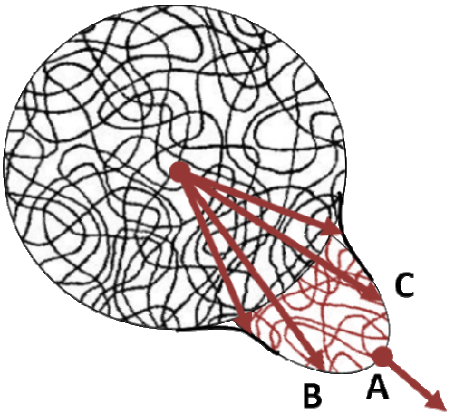

Figure 11. 'Systemicity' effects in amoebic model

This reflects the findings obtained in the study and shows that the model of amoebic growth developed to explain cost overruns can be also applied to the case of project delays. At the same time, it should be noted that the model is conceptual, aimed to enhance understanding of the topic and does not intend to quantify the phenomenon.

The present chapter discussed the findings by benchmarking them against the existing theoretical base in three main areas – reasons for delay in ERP implementation projects, project complexity dimensions and linkages between them. Both frameworks (on the reasons for delay and the complexity dimensions) were complemented by the findings of the present study. The chapter concludes with a discussion of the conceptual model for the linkage between complexity and delay, built after the existing model explaining cost overruns (Eden et al., 2005). The following chapter brings to a close the study by summarizing main findings and answering the research question, discussing credibility of the study based on its strengths and weaknesses as well as suggesting future research lines of inquiry.

CHAPTER 6 - CONCLUSION

The chapter concludes the study and is structured in the following way. It starts with a short summary recapitulating the research undertaken and discussing the answer to the research question. This is followed by the discussion of the theoretical and practical implications of the study. Further, credibility of the research findings and the mentioned implications is highlighted with a consideration of strengths and weaknesses of the research. The study is brought to a close with a discussion of possible future research lines of inquiry arising from it.

6.1. Summary

In the context of growing social complexification stemming from the rapid technological, political, economical and social changes, projects have evolved in the past decades form simple endeavors to complex, uncertain and quick undertakings (Laufer et al., 1996, cited in Williams, 1999a, p. 272). Thus, as complexity seems to have emerged as an omnipresent dimension in the project management field, there has been growing interest in the topic in the past years. While many authors associate it with project failures, little research has been done in this area and furthermore, to the best of our knowledge, there has been no study on the relationship of project complexity, in its broad sense, and the risk of delay. Therefore, this paper aimed to inquire the nature of this relationship and given the contextual nature of project complexity, the study focused on a particular sub-group of projects, ERP-implementation projects. Therefore, the research question was formulated as follows:

> **What is the nature of the relationship between project complexity and the risk of delay? (In the ERP-systems implementation projects context)**

In order to answer the question, the study started with an extensive literature review, covering both topics of project complexity and risk of delays. It particularly revealed that a holistic perspective on project complexity has recently emerged (Geraldi et al., 2011), which has not been applied in the studies on project time overruns. Thus, given the fact that the research field is an emerging one, an inductive approach was adopted. In order to pursue an in-depth study a case study research strategy was pursued, as it allowed the use of multiple data collection methods. In this respect, it information on nine ERP system implementation projects that had recorded delays was gathered through a series of semi-structured interviews and a set of questionnaires administered to each interviewee.

The answer to the research question is summarized in the following discussion. It has to be noted that since the study is of inductive nature, it aims to develop a hypothesis or a model of the phenomenon, rather than to prove or refute a pre-defined theory or hypothesis. It was identified that complexity in a broad sense represents a necessary condition for project delay (particularly, the delays beyond contingency limits). We cannot reasonably claim sufficiency of this condition, since the study was restricted to the projects that experienced delays. In addition, it was found that the actual mechanism underpinning the relationship varies according to the project complexity category concerned. Further, the study showed that although ERP projects are often considered to be technically complex, their complexity stems mainly from the subjective (or perceived) and uncertainty complexity dimensions. Finally, the conceptual model depicting the relationship in question was suggested. The model encompasses the research findings and satisfies the formal theoretical requirements for a 'good project complexity model' (Vidal & Marle, 2008, p. 1105).

6.2. Theoretical implications

The theoretical implications stemming from the study are three-fold and relate to studying project delays in ERP system implementation projects, enhancing understanding of the interplay between project complexity and delay, and of project complexity modelling. Each of the directions is discussed below in more detail.

Firstly, the study contributes to the body of knowledge on ERP system implementation projects, specifically regarding the reasons for projects delay. Indeed, only a few studies in the field are focused specifically on delays (Baraldi, 2009), whereas the majority investigates general reasons for project failures (Xue et al., 2005; Ehie & Madsen, 2005) or success factors of the systems adoption (Kerimoglu et al., 2008; Basoglu et al., 2007). Notably, several new reasons for delay, which were not encountered in the literature, have emerged in the study, such as working conditions of implementation team, project 'oversale', ambiguity of contract clauses and intrinsic motivation of the team members from client side. In addition, although it does not represent a focus of the study, the research allows comparison of findings on ERP system implementation projects with similar findings in different country or cultural contexts (Soja, 2008b; Kumar et al., 2003; Xue et al., 2005). At a glance there are country-specific differences that may be interesting to scrutinize in a focused study. As an example, only two out of eight reasons for project failures, identified in the study of the delayed projects in China (Xue et al., 2005), were also found in our study. This emphasizes context specificity of the project reasons for delay.

There are several notions on the central issue of the study, i.e. interplay between complexity and delay. To the best of our knowledge, this is the first study, addressing the relationship between project delay and complexity from a holistic perspective on complexity. Thus it contributes to the field, since other studies concentrate only on one or few of the dimensions (e.g. Tavares et al., 1999; Baraldi, 2009; Williams, 2005). Further, it was found that the framework encompassing four major complexity categories is a useful instrument to study project complexity. At the same time, the list of complexity parameters, compiled by Geraldi et al. (2011), was complemented with new parameters, particularly in dynamic and subjective categories of complexity. Finally, complexity (in the holistic sense) was found to be a necessary condition for delay beyond contingency limits.

Another implication of the study is that the amoebic model of cost overruns, developed by Eden et al. (2005), was showed to be applicable for the case of time overruns. Moreover, the graphical representation of the model was modified in order to explicitly reflect 'systemicity' effects. Particularly, the notion of tangled strands was developed to visualize the intricate interconnectedness of complexity measures. The pronounced ramification of project complexity dimensions uncovered in the study supports the corresponding theoretical proposition of Geraldi et al. (2011, p. 983) with empirical evidence.

6.3. Practical implications

From a managerial perspective, we cannot claim that the study provides panacea on how to deal with complexity in terms of specific procedures and actions which would help to completely avoid delays in various possible project contexts. Indeed, such a recipe is impossible due to the very nature of complexity, which makes it difficult to predict system behaviour as a response to management actions (Eden et al., 2005, p. 24). Instead, the study aims in the first place to help project managers to reflect on complexity dimensions of their projects, to elucidate the relationship between project complexity and delay, and to underline the perception-based character of project complexity. Nevertheless, several managerial implications are presented below regarding the most common issues in the considered case studies.

Firstly, project managers should treat ERP system implementation projects as organizational change endeavours. Although it is a common statement in the literature (Soja, 2008a, p. 106; Basoglu et al., 2007, p. 74), it was uncovered in the study that the practice is different. Unfortunately, IT consultants typically consider such projects as technical 'system implementations' while clients often adopt an erroneous attitude 'we bought the system'.

The second implication stems from the first one and is related to common underestimation in practice of certain components of complexity, in particular, uncertainty and subjective complexity. There was a strong emphasis on technical complexity among the interviewed project managers. However, the study suggests that it is often not the technical complexity itself, but the lack of information about this complexity or lack of participative attitude among client representatives that represents a problem, thus managerial efforts should be refocused towards these issues.

Particularly, more attention should be paid to subjective dimension, ensuring client employees involvement and motivation, top-management support and adequate level of communication. Similarly, uncertainty components should be scrutinized from the bidding phase since it was found that the lack of knowledge of sales team and client on system capabilities causes misperception, 'oversale' and ambiguous contract clauses. One of the possible ways to investigate these complexity dimensions and understand risks better is to separate 'diagnostic' part of project from implementation part; this can allow unveiling the subjective and uncertainty components of complexity earlier without committing to certain time scale of the whole project.

Thirdly, the complexity framework, which was based on extensive literature review and augmented in the study, may be used by project managers to assess the project complexity and to structure lessons learnt regarding the issue. It can also suggest to look into some issues which otherwise would be overlooked, due to comprehensive list of complexity parameters in the framework.

Finally, the mentioned interconnectedness of complexity categories poses another important implication. Specifically, if there are indications of project complexity from one of the perspectives (i.e. complexity categories), project manager should scrutinize others to ensure understanding of the situation; otherwise 'partial' managerial responses may worsen the situation and cause even greater delay.

6.4. Strengths and weaknesses of the study

The choice of methodology brought a set of strengths to the present research. First, the interpretivist stance of the study allowed researchers to grasp the complexity of the topic by conducting an in-depth study through its focus on perceptions. Thus rich insight was gained from the exploration of various points of view on the relation between project complexity elements and the reasons of delay, as the multiple intricacies between them were brought to surface.

Another strength of the study comes from one of the main advantages of the case study research strategy, the use of multiple sources of evidence. Therefore, researchers were able to study the relationship between project complexity and project delay form various angles and consequently to have a broader picture of the phenomena, as more data collection methods were pursued. Thus the case study approach proved to be a suitable choice given the explanatory nature of the research. On one hand, the semi-structured interviews helped researchers gain a deep understanding on the main reasons of delay and on the complexity elements underneath them. On the other hand, the questionnaires brought an assessment of the impact of various complexity elements on project delay, confirming in part the interviews data and thus strengthening the credibility of the initial findings. Moreover, the questionnaires data also brought additional information, revealing complexity elements that characterized the projects and had an influence on delay, but which could not have been inferred from the interviews responses.

The credibility of the study was further strengthened by its narrow focus on a particular sub-group of projects (ERP implementation projects carried out by IT consulting companies). Thus the sampling technique played an important role in gathering representative data. For example, the snowball effect contributed to the homogeneity of the data collected as the first interviewees provided researchers leads for similar cases.

Furthermore, in the context of a growing societal complexity that inevitably propagates in the business environment, leading to complex projects, the topic is of great interest for both academia and practitioners as it was also indicated by the UK government-funded research network – Rethinking Project Management Network. Thus the study discusses current problems of the project management field that were addressed in the literature, but for which little empirical data existed. As an example, the research confirmed the trend of tighter time constraints observed by Williams (1999a, p. 272), as the fast delivery of projects has become a success criteria in winning bids, and discussed its implications in the studied projects.

However, the study also presents several limitations, which should be considered in future research. First, each project was analysed from a singular point of view, as only one person from the project team was interviewed. Thus the data collected is limited to the interviewees' interpretations and perceptions of the events. Diverse views on the projects' level of complexity and their reasons of delay would have strengthened the validity of the study, overcoming the possible bias of the interviewees.

Another restraint of the study is brought by the limitations of the frameworks used. Although the template used for the complexity categories was based on the most recent and comprehensive literature review, which was also completed with new categories that emerged from the data analysis process, it might still lack several relevant elements. In spite of the fact that uncertainty and perceived complexity proved to occur more often and to have a greater impact, there is still a predominance of structural complexity factors in the framework.

The cross-sectional nature of the research also brought several limitations in regards to the study of the dynamic dimension of complexity. Thus, given the significance and the frequency of changes that occur during an ERP-implementation project, it would be worthwhile to conduct a longitudinal study in order to understand better the interrelations between dynamic complexity and the other categories.

Furthermore, the present research was focused only on the perspective of consulting companies on the topic. It would be interesting to investigate the problem also from the clients' perspective. This could shed light on the reasons of their lack of motivation and involvement and other aspects that were highly criticized by consultants. Moreover, this might also bring to surface possible shortcomings or biases from the consultants' side that were not disclosed in the interviews as participants might not have been comfortable to discuss or simply did not acknowledge them.

Overall the literature on the topic regarding the relationship between project complexity and the risk of delay is scant and thus there are a limited number of studies that can be used to compare the findings of the research. This calls for the need to further inquire into the topic and to try to overcome the limitations present in this research. The next section presents the possible future lines of inquiry emerging from the study.

6.5. Further research suggestions

There are several lines of future research that can emerge from the present study, which would expand the current boundaries of knowledge.

Given the inductive nature of the present research and the shortage of empirical data on the topic in the literature, it would be interesting to study the holistic project complexity theory in a quantitative study on a larger sample or to conduct a similar study to test the generalisability of the findings.

Another line of inquiry that was also mentioned in the previous subsection would be a "360 degree" study that would incorporate the views of various stakeholders involved in the project, particularly the client's employees. Thus various perceptions could be analysed and researchers could have a better picture of the line of events and the reasons underneath them.

Considering the contextual nature of complexity, a possible future research could investigate the relationship between project complexity and the risk of delay in a different setting, such as a different industry, in order to draw comparisons between studies. A new context could also be represented by different country given the importance of the cultural environment emphasised by several authors. For example, Soja (2008b), who studied a number of ERP system implementation projects in Poland claimed that there are several differences regarding the reasons of delay in developed and developing economies (pp. 45-46).

The authors do believe that complexity is highly relevant research topic nowadays, particularly in relation to the project management inherently incorporating different components of holistic complexity. Although it is doubtful whether it is possible (even theoretically) to 'manage' the project complexity due to its very nature, it is our belief that the reflection on the issue supported by the research on its implications may help to improve managerial decisions in times, when the society itself is becoming more and more complex. Thus, this study represents a step towards this aim by establishing the link between holistic complexity and project time overruns.

APPENDICES

Appendix 1 – Interview questions (general guidelines)

General questions

1. Could you tell us about the project? (client, duration, team, delay)

Project delay

2. Why the project was delayed?
3. How did it evolve over time?
4. What was done to prevent/react on the delay?

Project complexity

5. Was the project complex? How complex was it? (subjective opinion)
6. How would you describe why was it complex?

<u>Structural - Technological</u>

7. To what extent the project was technically complex?

<u>Structural - Organizational</u>

8. How complex was it from organizational point of view? (Project system's size/scale, variety, interdependencies)

<u>Uncertainty</u>

9. To what extent the team felt lack of knowledge/information (ambiguous goals/specifications, lack of competences, the company and project team experience/new industry, information from client,)
10. Novelty
11. Inherent uncertainty

<u>Perceived/Subjective</u>

12. To what extent there was a fit in perception between different stakeholders? (objectives, approaches, importance)
13. To what extent and how emotional aspects influenced the project? (personality clashes, motivation, trust, resistance to change)
14. What was the influence of socio-political 'games' on the project? (Power relationships, support/objection from stakeholders)

<u>Dynamics</u>

15. Did any significant changes appear during the project development? (New requirements & Change requests, stakeholders)
16. What was the pace of the project?

Appendix 2 - Complexity categories identified

Table 1. Structural complexity – data categorization

	CODE	Project	Evidence from interviews
Technological	BR. SCOPE	Project 4	"The project itself was concerned with SAP Implementation for 4 companies: production plant and export operations, metal processing and sales, two companies which cut pipes and sell them".
	CONFL.REQ.		
	NO.ACTIV.		
	NO.TECH	Project 1 Project 7	"The company products are complex – airplanes." "Big functional volume was required for the system."
	SYST.FIT	Project 1 Project 4 Project 2 Project 5 Project 6 Project 8	"another system for product life cycle management was being implemented at the same time and our project should have been integrated with it" "overall strong misfit between SAP functionality and existing business processes" "we could not see what is going on in Indian system, and they could not see what is going on in our system (because of technical limitations)." "There were problems with data migration, because of entry duplicates." "Data misfit in the system, duplicities." "The product did not fit the client's architecture and in order not to lose the client the team had to elaborate the product."
	TECH.INTER.	Project 4 Project 8	"The existing system which was used for payroll accounting was interrelated with 148 other systems"; "There was a complex IT infrastructure."
	PROCESSES	Project 1 Project 4 Project 5	"Dozens of shops (production). All these shops have their peculiarities" "they developed the conception 80/20 – 80% of SAP standard, 20% of the tailored development. It was impossible to do because of different business directions… mining is quite simple business, and here it's complex one, because it's client oriented." "company accommodated three different businesses (based on product lines) with own peculiarities all of which have to be incorporated in one system"
	SPECIALT.		
Organizational	PR.TEAM	Project 1 Project 4 Project 7 Project 8	"2 consulting companies"; "Quite big functional – Project Management, Production, Finances etc." "more than 300 consultants" "50 consultants and 50 internal team members" "50-100 team members; 4 consulting companies"
	HR.AVAIL.	Project 1 Project 4	"There was no dedicated project manager from the client side in the beginning. Only after a year it was appointed, before they had to work via the partners (business consulting company) and that was not efficient ("Chinese whispers")"; "no business representative to organize the internal work"; "Databases were not filled on time…only one person was assigned to this task, scheduled at 50% of working

		Project 5 Project 8 Project 9	time."; "You need to involve more people"; "The accountants did not participate at all"; "For 1,5 nobody allowed project leaders to speak with business representatives and future users" "team was organized inappropriately" "Work from the client was not organized … started to organize on their own (although it was not their responsibility)"; "Only one person from the client side" "No separate group for filling databases …filling databases/reference books was a major issue since there are dozens of thousands entries… was not ready on time"; "Key users were supposed to spend 30-50% of their time on the project, but in fact it was 5-10%."; "Their PM was not very motivated and / or did not have enough resources"
	NO.STAKEH.	Project 7	"Large number of people is involved and affected by the project"
	CONCUR.PR.	Project 1 Project 9	"there was another system… implementing at the same time so people had to check data for both" "then part of consultants were assigned to another project in parallel"; "finance module implementators have problems because they had to do the project in parallel"
	ORG.STRUCT.	Project 7	"Hierarchical management organization system (10 people were needed to approve your meeting with business representative + wrong decisions because of 'Chinese whispers')."
Contextual	NO.LOCATION	Project 7	"The tenth person for example sits in US and the first in Moscow."
	TIME ZONES		
	MULTI-CULT.	Project 3 Project 4 Project 2	"The [client] head office misunderstood the cultural environment of the local branch"" "…assigned a manager from Brazil.. he did not know Russian language"; "another partner [highest rank in consulting] was an Italian"; "use subcontractors from India " "project was sold by a Belgian manager "; "Indian ABAP programmers"
	STR.ALIGN.	Project 4	Client wanted to pursue a low cost strategy but implemented a project that required considerable resources. "The client decided to save money": " they developed the conception 80/20 – 80% of SAP standard, 20% of the tailored development. It was impossible to do because of different business directions… we were forced to write "to be" solution without the analysis of "as is" situation … They took as a template the solution previously implemented for mining division, but it was not suitable at all for different businesses".
	COMPLIANCE		
	AV.FACILITIES	Project 1	"Comfortable working conditions were not provided. First we sat with the company staff and later were given a tiny room for the whole team. For the first two months occasionally there were problems with electricity and Internet"

	BUDGET		
	TIME.PRESSURE	Project 1	"executives agreed on 9 months duration, it was clear that it is impossible to deliver the result during this period"; "we agreed because the crises has started and we required projects."
		Project 2	"this project was sold by a manager who did not understand the context specifics. So the duration was severely underestimated"
		Project 5	"Also our mistake – 'oversale'. If you write in the contract more than you can do, there always will be a person who will point it out"
		Project 8	"In fact, the conceptual phase has lasted for 6 months instead of 7 weeks. The scope of work was underestimated."
		Project 9	"The duration was too small … in order to win the contract."

Table 2. Epistemic uncertainty – Imperfect/Unavailable information in the project context – data categorization

	CODE	Project	Evidence from interviews
STAKEH.NOV.	NEW.TO.COMP.	Project 5	"each project is unique and for sure you will meet something completely new in the particular setting"
		Project 7	"Some issues (business processes peculiarities) were completely new for the project team"
		Project 9	"Some issues have never been encountered by anyone in the consulting company. Every project is actually unique which makes it complex."
	NEW.ORG.STR.		
LACK.COMP.	ORG. MATURITY	Project 1	"overtime work was not organized, although it is absolutely necessary for such projects" – lack of organization "There was no dedicated project manager from the client side in the beginning. Only after a year it was appointed, before they had to work via the partners (business consulting company) and that was not efficient ("Chinese whispers")"; "no business representative to organize the internal work"; "
		Project 4	"The client was not prepared for such a large scale project"; "Poor management"; "They wanted necessarily that the main project manager of the project to be a foreigner. The company assigned a bad manager"; "they made several wrong managerial decisions"
		Project 9	"Bad organization of internal team: sometimes PM from the team side was programming himself to transform an old database to the required format… no separate group for filling databases, although it is a big separate task"
	PM.COMP.	Project 3	"Project manager from the client's side did not have enough skills to implement the project
		Project 4	"They wanted necessarily that the main project manager of the project has to be a foreigner. The company assigned a bad manager, who additionally did not know Russian language, and of course all internal company

		Project 9	documentation was in Russian (and he was the only foreigner on the project).”; “project manager from the client side did not have enough competences and experience with ERP systems” “people on the project had less than two years of experience”
	STAKEH.COMP.	Project 1	“nobody knew which software systems exist”
		Project 2	“Subcontractors were not knowledgeable and lacked competences.”
		Project 5	“The representative was a new person in the company and did not know certain bureaucracy, norms, templates of documents and behavior elaborated during previous ERP implementation projects in the holding. The person did not familiarize herself with the company documentation.”
		Project 4	“subcontractors will do in two days the same work which consultant will do in 15 minutes”,” I don’t know any ‘development’ work which I as a consultant would not redo afterwards. “
		Project 7	“Business representatives did not know how the system works.”; “Not enough knowledge and competences from the client’s side.”
		Project 8	“It was felt a lack of technical specialists in the client’s team.”
		Project 9	“Low level of … computer literacy of the future users”
CLARITY	PR.EL.CLARITY	Project 1	“No clear goals/objectives “; “nobody knew… what are the project objectives and requirements”
		Project 4	“Ambiguous goals.”; “No real planning and schedule. All team leaders set their own goals themselves … but what should be done for this and how – not clear.”
		Project 5	“It was very difficult to manage scope, because many contract clauses could be interpreted differently”
		Project 6	“There was no clear task set (with a timeline, during certain project phase) to ensure data migration (within client team).”
		Project 7	“The requirement were not formalized enough and were very general”;” Ambiguous requirements”
	UNIDEN.STAKE		
DATA.AVAIL.		Project 1	“There were also some peculiarities in the client’s processes, and nobody told consultants about them.”;
		Project 4	“There was a lack of information in electronic format about production process”
		Project 9	“Not enough information – no feedback. The senior managers had weekly status discussion but nobody communicated it further, not even to the level of team leaders.” “Lack of information mostly because of the lack of involvement …Some specific aspects of the client’s business only they knew, and it was discovered only at the end, after the conceptual, architecture phase etc. …Only if you ask they will respond”

Table 3. Perceived complexity – data categorization

	CODE	Project	Evidence from interviews
Common understanding	SHARED.VISION	Project 1	"the business consultants and the client had divergent opinions – business consultants wanted to change the process significantly, and the client wanted to preserve the old system maybe with some adjustments."
	UNDERST.IMPL.	Project 2	"Project was sold by a manager who did not understand the specifications. So the duration was severely underestimated."
		Project 5	"Finally they develop something, transfer it to testing system, I enter it and see that part of the settings are not done."
		Project 4	"Misunderstanding of SAP capabilities by the client" "developed the conception "80/20" – 80% of SAP standard, 20% of the tailored .... It was impossible to do because of different business directions"; "They took as a template the solution previously implemented for mining division, but it was not suitable at all for different businesses"
		Project 7	"As the client does not have enough knowledge, he relies on what the consultant is explaining to him, and often understands something different."
		Project 9	"The client has a wrong idea about capabilities of SAP solution. They require to use standard SAP functions … although it was not possible."; "Client employees did not realize fully that they will have to work with this system for many years."
	UNDESRT.RESP.	Project 1	"employees asked me to check whether they did it right dozens of times (and this was not my work)."
		Project 4	"but some business representatives were afraid to approve documents and take responsibility"
		Project 5	"started to organize on their own (although it was not their responsibility)"
		Project 6	"ensure data migration ... It was not clear who should do this"
		Project 8	"There was not clear who was a supervisor in the integrators' teams, who is responsible for some parts"
		Project 9	"there were issues of communication and responsibility division."
	SETTING.CLAR.		
Socio-political games	SEN.MNG.SUPP.	Project 1	"Lack of top management support"
		Project 4	"no support from project sponsors and executives"
		Project 5	"No support from the project sponsor."
	STAKEH.COMM.	Project 1	"The CEO was not interested, future users were not interested etc."; "Low level of administrative support. "
		Project 2	"involvement of low-paid programmers did not pay off"'; "The chief accountant was not particularly interested in the project."; "First all people were resistant to change"
		Project 4	"Another Partner once he gathered the project managers involved in the project and said …"I don't care about this project, because in half a year I will go home …I am not really interested in it"; "The accountants did not

			participate at all, because they were told by their management that there will be a major downsizing and that demotivated them."; "group was responsible for change management. There were 10 people and they did nothing, besides motivation posters on walls."
		Project 5	"Business [future users] did not participate, started to participate only closer to the end of project"; "People are always afraid of change."
		Project 6	"There was no clear task set to ensure data migration (within client team)...Finally this really painstaking task was done by the consultants".
		Project 7	"some of the employees were not ready to discuss the matter in a detailed way"
		Project 9	"There was only a limited involvement of business representatives in the project, especially during first several months "it was not their deal", and some people even thought that it is temporarily and finally they will be left alone"; "Key users were supposed to spend 30-50% of their time on the project, but in fact it was 5-10%. The project was of secondary importance for them as they were mainly accountable to their managers for their daily departmental work."; "Users resistance to change. And lack of involvement"
	REAL.EPXECT.	Project 1	"It is not clear why our executives agreed on 9 months duration, it was clear that it is impossible to deliver the result during this period"
		Project 5	"Also our mistake – 'oversale'. If you write in the contract more than you can do, there always will be a person who will point it out"; "Misunderstanding of SAP capabilities by the client. Tried to put a variety of functions in the model…There are many financial and time limitations in the project but the representative didn't want to understand them"
		Project 9	"From the philosophical standpoint people always count to get maximum, and finally they get what they get".
	POWER.STRUG.	Project 1	"The employees were motivated financially, and that brought quarrels in the project team"
		Project 3	"The local branch representative tried to pursue his own interests by working with the partner company."
		Project 4	"Always conflict of interests in the alliance companies"
		Project 9	"All of the employees were motivated financially. But this brought additional quarrels about size of premium, jealousy etc."
Emotional aspects	COMMUNICAT.	Project 1	"There were also some peculiarities in the client' processes, and nobody told the consultants about them."; "There was no dedicated PM from the client side in the beginning…before they had to work via the partners and that was not efficient ("Chinese whispers")"
		Project 2	"I write explanations again on the settings which were not taken into account"
		Project 4	"For 1 year and a half nobody allowed project leaders to speak with business representatives and future users."
		Project 7	"It is very difficult to inform all participants who can be affected or should be involved. You can send them emails, but you cannot guarantee that they will read it,

		Project 9	and if they will, that they will understand it correctly, and if they will, that they will do what you want when you want." "there were issues of communication"
	SOC.INTEGR.		
	PERSON.CLASH	Project 9	"Several personal clashes"
	EMPATHY	Project 2 Project 9	"no trust" "While some employees were trustworthy, other were not."
	MOTIVATION	Project 1 Project 2 Project 4 Project 9	"Level of motivation was fantastically low." "No motivation" "The accountants did not participate at all, because they were told by their management that there will be a major downsizing and that demotivated them." "Another group was responsible for change management. There were 10 people and they did nothing, besides motivation posters on walls. They were not evaluated on how business was actually prepared for change." "Low motivation of staff"; "Their project manager was not very motivated"

Table 4. Dynamic complexity – data categorization

CODE	Project	Evidence from interviews
CHANGE.REQ.	Project 1 Project 4 Project 5	"Until this moment the decision was made to run production start only for some of the company's products (one product group). But the new owners demanded to run the production for other product group. Thus the project objectives were changed" "shift from unified to tailored solutions" "Many additional requirements during the project."
CHANGE.STAKE.	Project 1 Project 8	"Project sponsor from the client side was changing all the time" "In the conceptual phase the integrator company was changed"
CHANGE.STRTG.	Project 5	"First they wanted to merge the company with another one (which had completely different business model, i.e. included logistics) but later cancelled the process, although a lot of effort and time was devoted to it"
CHANGE. LEGISL.	Project 4	"Change of legislation (VAT)"

Appendix 3 - Connection between categories of complexities and identified delays

Table 1. Connection between reasons of delay and complexity categories

Reason for delay	Complexity dimension	Explanation
COMP.SOL	SYST.FIT TECH.INTER.	*Project 8*: The testing phase was delayed due to the technical complexity of the solutions implemented. First, there were problems with the technical and infrastructural integration (SYST.FIT) as the product did not fit the client's architecture and thus had to elaborate the product. Second there was a complex IT infrastructure (TECH.INTER).
SYST.INT	SYST.FIT	*Project 1:* In the middle of the implementation process, the consultant found out that the ERP system needed to be integrated with the product life cycle management that was being put into effect in the same time (SYST.FIT) which required extra work that led to delays.
ERP.CUSTOM	PROCESSES NEW.TO.COMP. PM.EXPER. DATA.AVAIL. COMMUNICAT.	*Project 1:* The client's processes had several peculiarities as there were a high number of production shops, each one having its own distinctive characteristics (PROCESSES). Given the communication problems in the team, no one informed the consultants about these traits, which led to an inappropriate customization of ERP, the further led to reworks and finally delays (COMMUNICAT.; DATA.AVAIL.) *Project 9:* As some processes were new to the consulting company and the project managers did not have enough experience, some functional mistakes were made, which required rework, thus causing delays. (NEW.TO.COMP.; PM.EXPER.)
BPR	POWER.STRUG.	*Project 3*: There was interest from the local branch representative and the partner company, for the project to be carried on by the latter one and not by the consulting company. In this respect, the partner company used various means to influence this decision, including low quality of work (business process description) and delays (POWER.STRUG.).
LEG.SYST	SYST.FIT	*Project 6*: There was data misfit in the legacy systems as there were many duplicate entries for a single item that needed to be unified. This was a long process that finally had to be done by the consultants and caused delays (SYST.FIT).
PLAN.MAN.	HR.AVAIL. ORG.STRUCT. PM.EXPER. PR.EL.CLARITY UNDERST.IMPL. UNDESRT.RESP. STAKEH.COMM.	*Project 6*: There was no clear line of responsibility for tasks within the client team regarding the data migration process (UNDESRT.RESP.) and the stakeholders undermined its importance (UNDERST.IMPL.). Therefore the work had to be done in the end by the consultants, who did not know all the specifications of the data and thus there was

		high probability of mistakes. *Project 1:* The client assigned only one person who would allocate 50% of his time to fill the databases, which was clearly not enough (HR.AVAIL.). Therefore the task was not fulfilled on time. Furthermore, the overtime work was not well organized although it was essential for the project success. *Project 9:* There was bad organization in the client's team. First, there was no separate group for filling databases (HR.AVAIL.). Second there was low involvement from the key users who dedicated only 5-10% of their time instead of the planned 30-50% (STAKEH.COMM.; MOTIVATION). Third, there was no clear division of tasks, as the project manager from the team side was also programming (UNDESRT.RESP.). *Project 3:* The project manager form the client's side did not have the required competences to implement the project (PM. EXPER.) *Project 8:* The testing team was badly organized (ORG.STRUCT.)
CONTROL	HR.AVAIL POWER.STRUG.	*Project 3*: The partner company wanted to implement the whole project by itself and thus was not interested in handing in their work on time to the consulting company. Thus, their part took too much time, leading to delays (POWER.STRUG.). *Project 9*: There was bad organization of the internal team and there was no separate team assigned to fill in the databases, which was a very comprehensive and time consuming task (HR.AVAIL.). Therefore the task was not ready on time.
TRAINING	STAKEH.COMP.	*Project 9*: The future users lacked basic competences such as computer literacy (STAKEH.COMP.). Therefore consultants had to spend much more time than usual for providing training.
COMMUN.	SYST.FIT ORG.STRUCT. UNDESRT.RESP. COMMUNICAT.	*Project 1*: In the beginning there were communication problems in the team because there was no project manager from the client's side and everything was done via partners, which led to a "Chinese whispers" effect (COMMUNICAT.). *Project 7*: The complexity of the approval process also led to communication problems, as the consultants had to inform all the participants involved, which seemed to be a difficult task in itself and it was not even sure whether the latter will read the emails and understand correctly the message (ORG.STRUCT.; COMMUNICAT.). *Project 2*: Due to lack of technical integration, the consultants did not have access to the programmer's systems and vice versa, which hindered the communication process. (SYST.FIT; COMMUNICAT.). This work organization caused serious delays because consultants had to spend considerable time on making print screens and

		writing explanations, which were not fully understood by the programmers and developed solutions that needed rework. *Project 8*: The line of responsibility was not clear in the integrators' teams as consultants were not sure who were the supervisors to whom they could address certain issues, making the communication process difficult (UNDERST.RESP.; COMMUNICAT.).
PROJ.MAN.	TIME.PRESSURE PM.EXPER. STAKEH.COMP REAL.EPXECT.	*Project 7*: The persons who planned and sold the project (PMO) did not take everything into account and underestimated the duration of the project, creating unrealistic expectations (TIME.PRESSURE; REAL.EPXECT.). The development of the 'blue print' paper took four months instead of the pre-established two months (PM.EXPER.; STAKEH.COMP).
WORK.COND.	AV.FACILITIES	*Project 1*: The client did not provide appropriate facilities for the project team, as they were given a small office, which occasionally had electricity problems as well as internet connection problems (AV.FACILITIES).
CHANGE	STR.ALIGN. UNDERST.IMPL. CHANGE.REQ. CHANGE.STRTG. CHANGE.STAKE.	*Project 5:* During the implementation of the project it was a change in the strategy, regarding the possible merger with another company, which subsequently changed the requirements of the project and contributed to the delay (CHANGE.STRTG/ CHANGE.REQ.). *Project 1:* The change of project's sponsor led to changes in the project's objectives (CHANGE.STAKE.; CHANGE.REQ.). For example, new owner wanted to run the production for a different product group than the one established initially. *Project 4:* The client has misunderstood the implications of the ERP system and wanted to pursue a low cost strategy by keeping 80% of SAP standard and in the same time wanted to achieve unification of processes (UNDERST.IMPL.; STR.ALIGN.). As the integration was not possible due to the different business directions, there was a change in requirements, which finally lad to 30 000 man hours of tailored development and writing interfaces with legacy systems which completely contradicted the initial unification plan, causing delays (CHANGE.STRTG.; CHANGE.REQ.).
MISFIT	PROCESSES ORG. MATURITY	*Project 5:* On one hand there was incongruence between the client's dynamic business and the system's requirements for stable processes and on the other, between the low number of future users and SAP's functionality designed for big systems (PROCESSES). *Project 4:* "The client was not prepared for such a large scale project, especially to the implementation of all-new "to be" processes based on best practices"

		– in terms of what?? Maturity? Resources?
STR.DECISIONS	UNDERST.IMPL. CHANGE.REQ.	*Project 9:* The client misunderstood the implications of the project, requiring the implementation of the standard version that would help them cut costs but was not possible (UNDERST.IMPL.). *Project 4:* The client misunderstood the implications of the project, which led to a series of bad managerial decisions: such as developing a standardized concept that did not fit their business characteristics, deciding to skip essential steps from the normal implementation process, using a simplified template for the implementation (UNDERST.IMPL.). In the end, when it was understood that their approach was not realistic they changed their requirements, thus causing delays.
OVERSALE	TIME.PRESSURE STAKEH.COMP UNDERST.IMPL. STAKEH.COMM. REAL.EPXECT.	*Project 5*: The consulting company oversold the project in order to win the bid, thus establishing shorter deadlines than it could be achieved, creating unrealistic expectations (STAKEH.COMM.; REAL.EPXECT.). Thus inevitably the tight time constraints were not met and the project recorded delays (TIME.PRESSURE). *Project 1*: The executives agreed upon a deadline that could not have possibly been met, creating unrealistic expectations and ending up with delays (STAKEH.COMM.; TIME.PRESSURE; REAL.EPXECT). *Project 2*: The manager who sold the project did not understand the specifications and underestimated the project duration (UNDERST.IMPL./ STAKEH.COMP). Thus it was established a completion time that could not be met, creating unrealistic expectations of stakeholders and leading to inevitable delays (TIME.PRESSURE; REAL.EPXECT). *Project 8*: The scope of the project was highly underestimated and thus the conceptual phase lasted 6 months instead of 7 weeks and thus the initial expectations were not met (STAKEH.COMP; TIME.PRESSURE; REAL.EPXECT).
CONTRACT	PR.EL.CLARITY	*Project 5:* Many contract clauses were not clear and thus could be interpreted in different ways, leading to additional work (PR.EL.CLARITY.).
CLIENT.SUP.	STAKEH.COMM. POWER.STRUG. MOTIVATION	*Project 1:* Due to some political reason, the technical director of the company negotiated with the CEO for his subordinates not to participate in the project. (POWER.STRUG.; STAKEH.COMM.). *Project 9:* The project manager form the client side did not seem very motivated and/or did not have enough resources (STAKEH.COMM.; MOTIVATION).
MNGMT.SUP.	SEN.MNG.SUPP.	*Project 9:* Only late were project sponsors involved in the project. Their support led to the publication of an internal policy that made the other stakeholders be active in the project (SEN.MNG.SUPP.). If the

		sponsor would have contributed from the beginning, there would have been a greater commitment from the rest of stakeholders, which would have decreased the probability of delay. *Project 4:* There was no support from project sponsors and executives and thus there was no strong voice to authoritative voice to argue with the business's wrong decisions that led to delays (SEN.MNG.SUPP.).
CULTURE	MULTI-CULT. COMMUNICAT.	*Project 4:* The multiculturalism in the team led to communication problems as the project manager was Brazilian and did not understand the Russian language, while all the project documentation was written in Russian. Furthermore, there was cultural misunderstanding between consultants and the Indian subcontractors which led to rework and thus to delays (MULTI-CULT; COMMUNIAT.). *Project 3*: The cultural clash between the head office and the local branch led to conflicting interests, which subsequently led to delays (MULTI-CULT.).
INVOLV.	STAKEH.COMM. MOTIVATION	*Project 1:* There was a very low level of motivation on the client's side, which was reflected in the lack of involvement of stakeholders. While no person from the technical director's team participated in the project, some of the future key users did not test properly the developed modules (STAKEH.COMM.; MOTIVATION) *Project 9:* There was very low motivation among the staff from the client's side, including the project manager, which led to a general lack of involvement of the business representatives, which is absolutely necessary in the testing period. In addition to that, the employees did not fully understand the implications of the project, as they saw it as something temporary, rather than as the system they will have to work with for years (UNDERST.IMPL.). Furthermore there was no clear line of responsibility for tasks as people were saying it was "not their deal" (UNDESRT.RESP.). All these led to delays in the integration tests. *Project 5:* There was lack of involvement from the future users, who start to participate only toward the end of the project, bringing reworks and subsequent delays (STAKEH.COMM.).

Appendix 4 – Questionnaire questions and responses

Overall, how would you rate on a scale from 1 to 5 the impact of the following elements on project delay? (1-very low, 2-low,3-medium, 4-high, 5-very high). If a certain element was not present/not applicable in the project, please fill in 0.				Project 1	Project 2	Project 3	Project 4	Project 5	Project 9
Project complexity	Structural	Scope	Breadth of project scope	4	1	1	5	4	2
			Project's objectives are not aligned with the company's strategy	1	1	3	3	2	1
		Budget	High financial scale of the project (budget of project)	3	1	3	4	2	3
		Technology	High number of technologies involved and their high level of interdependences in client's products and processes	3	1	3	5	3	2
			High number of IT systems to be replaced or interfaces to be written (in order to achieve technical and infrastructure integration)	3	1	2	5	4	2
		Business Processes	High complexity of business processes in client's organization	3	1	3	5	3	2
		Project's tasks	High number of tasks to be fulfilled in order to implement the project	3	2	3	5	3	3
			High interdependence between the tasks required to implement the project	3	1	2	4	2	3
		Project team & other stakeholders	Big size of the project team (high number of team members working towards achieving the goals of the project)	2		1	5	3	3
			High number of specialities involved in the project (multidisciplinarity; number of roles and level of labour specialization)	2	1	1	1	3	3
			High number of stakeholders (persons that have an interest in the project) and their interdependency	3	1	1	1	4	3
			High variety of cultures and languages spoken among team members and other stakeholders	0	1	1	2	3	0
		Client's organisational structure	High number and interdependencies between hierarchical levels (vertical structure)	2	1	1	4	2	3
			High number and interdependencies between organisational units (horizontal structure)	2	1	2	5	2	3
			Project manager's lack of control over human resource selection	2	2	1	5	4	3
		Project constraints	High number of concurrent projects (that limits resources availability for the present project)	2	3	1	1	3	1

			Long time until the client makes resources available for the project	3	2	2	4	3	3
			Tight time constraints	4	2	1	4	2	4
		Context	Multiple time zones	0	2	1	1	0	0
	Uncertainty	Technology	High degree of customization needed	3	1	1	3	4	3
			Technological and business processes are new to the consulting company	4	1	2	4	3	2
		Project team & other stakeholders	Lack of previous experience of project manager in similar projects	3	2	3	5	4	1
			Lack of previous experience of stakeholders in similar projects	1	2	3	5	4	3
			Stakeholders are not knowledgeable in relevant technical or business related issues	3	1	1	4	3	4
			Team members have not worked together before	3	1	1	3	1	3
			High reliance on key experts		1	1	1	2	
		Organization	Client's organizational inefficiency (operations, risk management, change implementation)	4	2	5	5	3	3
		Scope	Conflicting requirements of the project	0	1	4	5	4	0
		Project data	Unavailability or inaccuracy of data relevant for the project	1	1	2	4	3	1
	Perceived	Ambiguity	Team members do not have a common understanding regarding project's goals, requirements and performance measurements	1	1	1	5	4	1
			It is not clear for the team members what are their responsibilities in the project	1	1	1	5	3	2
		Social/Political	Unrealistic expectations of stakeholders regarding project's deliverables	3	1	2	4	4	2
			Lack of support and commitment from stakeholders (i.e. senior management, employees etc.)	3	1	2	5	4	2
			Conflicts, power struggles and hidden agendas between stakeholders	3	1	1	2	4	3
			Lack of trust and empathy among team members	3	2	1	3	3	4
			Inadequate communication between team members	1	3	1	3	3	1
			Personality clashes among the project team	2	1	4	4	3	4
	Dynamic complexity		Continuous changes in any of the element presented above during the project	4				4	2

REFERENCES

Adams, F.K. (2008). Risk perception and Bayesian analysis of international construction contract risks: the case of payment delays in a developing economy. *International Journal of Project Management*, 26 (2), 138-148.

Adlakha, V.G. (1989). A classified bibliography of research on stochastic PERT networks: 1966–1987. *INFOR*, 27 (3), 272–296.

Al-Momani, A.H. (2000). Construction delay: a quantitative analysis. *International Journal of Project Management*, 18, 51-59.

Arditi, D., Akan, G.T., & Gurdamar, S. (1985). Reasons for delays in public projects in Turkey. *Construction Management and Economics*, 3, 171–181.

Assaf, S.A., Al-Khalil, M., & Al-Hazmi, M. (1995). Causes of delay in large building construction projects. *ASCE Journal of Management in Engineering*, 11(2), 45–50.

Baccarini, D. (1996). The concept of project complexity - a review. *International Journal of Project Management*, 14(4), 201-204.

Baraldi, E. (2009). User-Related Complexity Dimensions of Complex Products and Systems (CoPS): A Case of Implementing an ERP System. *International Journal of Innovation Management*, 13 (1), 19–45.

Basoglu, N., Daim, T., & Kerimoglu, O. (2007). Organizational adoption of enterprise resource planning systems: A conceptual framework. *Journal of High Technology Management Research*, 18 (1), 73–97.

Bendell, A., Solomon, D., & Carter, J.M. (1995). Evaluating Project Completion Times When Activity Times are Erlang Distributed. *The Journal of the Operational Research Society*, 46 (7), 867-882.

Berny, J. (1989). A New Distribution Function for Risk Analysis. *The Journal of the Operational Research Society*, 40 (12), 1121-1127.

Bertelle, C., Duchamp, G.H.E., & Kadri-Dahmani, H. (2009). *Complex Systems and Self-organization Modelling*. Berlin: Springer.

Bhaskar, R. (1989). *Reclaiming reality: a critical introduction to contemporary philosophy.* London: Verso.

Biedenbach, T., & Müller, R. (2011). Paradigms in project management research: examples from 15 years of IRNOP conferences. *International Journal of Managing Projects in Business*. 4 (1), 82-104.

Bogdan, R., & Taylor, S.J. (1975). *Introduction to qualitative research methods: a phenomenological approach to the social sciences.* New York: Wiley & Sons

Bosch-Rekveldt, M. Jongkind, Y., Mooi, H., Bakker, H., & Verbraeck, A. (2011). Grasping project complexity in large engineering projects: The TOE (Technical, Organizational and Environmental) framework. *International Journal of Project Management*, 29 (6), 728-739.

Bryman, A., & Bell, E. (2003). *Business research methods.* 1st edition. Oxford: Oxford University Press.

Buckhout, S., Frey, E., & Nemec, J. Jr. (1999). Making ERP Succeed: Turning Fear Into Promise. *IEEE Engineering Management Review*, 27 (3), 116-123.

Casti, J. L. (1992). The simply complex: trendy buzzword or emerging new science? *Bulletin of the Santa Fe Institute*, 7, 10-13.

Casti, J. L. (1995). *Complexification: Explaining a Paradoxical World Through the Science of Surprise*. New York: Harper Collins Publishers.

Chartered Institute of Building. (2008). *Managing the risk of delayed completion in the 21st century.* Ascot: Chartered Institute of Building.

Cicmil, S., & Marshall, D. (2005). Insights into collaboration at project level: complexity, social interaction and procurement mechanisms. *Building Research and Information*, 33 (6), 523-535.

Cicmil, S., Williams, T.M., Thomas, J., & Hodgson, D. (2006). Rethinking project management: researching the actuality of projects. *International Journal of Project Management*, 24 (8), 675–686.

Cleland, D. I., & Ireland, L. R. (2007). *Project management : strategic design and implementation.* 5th ed., New York: McGraw-Hill.

Cooke-Davies, T., Cicmil, S., Crawford, L., & Richardson, K. (2007). Mapping the Strange Landscape of Complexity Theory and Its Relashionship to Project Management. *Project Management Journal*, 38 (2), 50-61.

Cotsaftis, M. (2009). A Passage to Complex Systems. In C. Bertelle ed. *Complex Systems and Self-organization Modelling*. Berlin: Springer.

Davenport, T.H. (1998). Putting the Enterprise into the Enterprise System. *Harvard Business Review*, July-August, 121-131.

Dodin, B., & Sirvanci, M. (1990). Stochastic networks and the extreme value distribution, *Computers and Operations Research*, 17 (4), 397-409.

Eden, C., & Williams, T. (2000). The role of feedback dynamics in disruption and delay on the nature of disruption and delay (D&D) in major projects. *Journal of the Operational Research Society*, 51 (3), 291-300.

Eden, C., Ackermann, F., & Williams, T. (2005). The Amoebic Growth of Project Costs, *Project Management Journal*, 36 (1), 15-27.

Edmonds, B. (1999). *Syntactic measures of complexity.* Doctoral dissertation. Manchester: University of Manchester.

Ehie, I., & Madsen, M. (2005). Identifying critical issues in ERP implementation, *Computers in Industry*, 56, 545-557.

Elmaghraby, S.E., & Herroelen, W.S. (1980). On the measurement of complexity in activity networks. *European Journal of Operational Research*, 5, 223-234.

Elmaghraby, S.E. (2000). On criticality and sensitivity in activity networks. *European Journal of Operational Research*, 127, 220–238.

Faridi, A.S., & El-Sayegh, S.M. (2006). Significant factors causing delay in the UAE construction industry. *Construction Management and Economics*, 24, 1167–1176.

Fente, J., Schexnayder, C., & Knutson, K. (2000). Defining a probability distribution function for construction simulation. *Journal of Construction Engineering & Management*, 126 (3), 234-241.

Galbraith, J.R. (1977). *Organization Design*. Reading: Addison-Wesley.

Golenko-Ginzburg, D. (1988) On the Distribution of Activity Time in PERT. *The Journal of the Operational Research Society*, 39 (8), 767-771.

Grabher, G. (2002). Cool Projects, Boring Institutions: Temporary Collaboration in Social Context. *Regional Studies,* 36 (3), 205-214.

Gray, C.F., & Larson, E.W. (2008). *Project Management: The Managerial Process*, 4th ed., New York: The McGraw-Hill Companies Inc.

Grassberger, P. (1989). Problems in Quantifying Self-organized complexity. *Helvetica Physica Acta*, 62 (5), 489-511.

Griffin, A. (1997). The Effect of Project and Process Characteristics on Product Development Cycle Time. *Journal of Marketing Research*, XXXIV (Feb.1997), 24-35.

Geraldi, J. G., & Adlbrecht, G. (2007). On faith, fact and interaction in projects. *Project Management Journal*, 38(1), 32-43.

Geraldi, J.G. (2009). What complexity assessments can tell us about projects: dialogue between conception and perception. *Technology Analysis & Strategic Management*, 21(5), 665-678.

Geraldi, J.G., Maylor, H., & Williams, T. (2011). Now, let's make it really complex (complicated): A systematic review of the complexities of projects. *International Journal of Operations & Production Management*, 31 (9), 966-990.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln, ed. *Handbook of qualitative research*. London: Sage. pp. 105-117.

Hardie, N. (2001). The prediction and control of project duration: a recursive model. *International Journal of Project Management*, 19, 401-409.

Hobday, M. (1998). Product complexity, innovation and industrial organisation. *Research Policy*, 26, 689-710.

Jaafari, A. (2001). Management of risks, uncertainties and opportunities on projects: time for a fundamental shift. *International Journal of Project Management*, 19 (2), 89-101.

Jaafari, A. (2003). Project management in the age of complexity and change. *Project Management Journal*, *34*(4), 47-57.

Kaimann, R.A. (1974). Coefficient of Network Complexity. *Management Science*, 21(2), 172-177.

Kerimoglu, O., Basoglu, N., & Daim, T. (2008). Organizational adoption of information technologies: Case of enterprise resource planning systems. *The Journal of High Technology Management Research*, 19 (1), 21-35.

Koushki, P.A., Al-Rashid, K., & Kartam, N. (2005). Delays and cost increases in the construction of private residential projects in Kuwait. *Construction Management and Economics*, 23, 285–94.

Kumar, V., Maheshwari, B., & Kumar, U. (2003). An investigation of critical management issues in ERP implementation: empirical evidence from Canadian organizations. *Technovation*, 23, 793–807.

Larson, E., & Gobeli, D. (1989). Significance of Project Management Structure on Development Success. *IEEE Transactions on Engineering Management*, 36 (2), 119-125.

Lee, D.E. (2005). Probability of Project Completion Using Stochastic Project Scheduling Simulation. *Journal of Construction Engineering and Management*, 131 (3), 310-318.

Lee, G., DeLone, W., & Espinosa, J.A. (2007). Ambidexterity and Global IS Project Success: A Theoretical Model. In 40th Hawaii International Conference on System Sciences. Hawaii, January, 3-6.

Lim, C.S., & Mohamed, M.Z. (2000). An exploratory study into recurring construction problems. *International Journal of Project Management*, 18 (3), 267–73.

Lu, M., & AbouRizk, S.M. (2000). Simplified CPM/PERT Simulation Model. *Journal of Construction Engineering and Management*, 126 (3), 219-227.

Lundin, R., & Söderholm, A. (1995). A theory of the temporary organization. *Scandinavian Management Journal*, 11, 437-455.

Lundin, R., & Söderholm, A. (1998). Conceptualizing a projectified society: discussion of an eco-institutional approach to a theory on temporary organizations. In: Lundin, R. & Midler, C., (eds). *Projects as arenas for learning*. Norwell, MA: Kluwer Publishing.

Maylor, H. (2001). Beyond the Gantt Chart: Project Management Moving on. *European Management Journal,* 19 (1), 92-100.

Maylor, H., Brady, T., Cooke-Davies, T., & Hodgson, D. (2006). From projectification to programmification. *International Journal of Project Management,* 24 (8), 663-674.

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.

Meyer, M., & Utterback, J. (1995). Product Development Cycle Time and Commercial Success. *IEEE Transactions on Engineering Management*, 42 (4), 297-304.

Midler, C. (1995). Projectification of the firm: the Renault Case. *Scandinavian Journal of Management*, 11(4), 363-375.

Miles, M.B., & Huberman, A.M. (1994). *Qualitative Data Analysis.* 2nd ed. London: Sage Publications.

Miller, E. J. (1959). Technology, territory, and time: the internal differentiation of complex production systems. *Human Relations,* 12 (3), 243-272.

Mintzberg, H. (1991). The *Structuring of Organisations.* New Jersey: Prentice-Hall.

Müller, R., & Turner, J. R. (2007). Matching the project manager's leadership style to project type. *International Journal of Project Management*, 25, 21-32.

Müller, R. (2011). Project Management Postgraduate Lecture, Umeå School of Business, Umeå, Sweden. 2011-11-28.

Müller, R., Geraldi, J., & Turner, J. R. (2011). Relationships Between Leadership and Success in Different Types of Project Complexities. *IEEE Transactions on Engineering Management*, 99 [published online 14th of March, 2011, http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5730485].

Nassar, K.M., & Hegab, M. Y. (2006). Developing a Complexity Measure for Project Schedules. *Journal of Construction Engineering & Management*, 132 (6), 554-561.

Nassar, K.M. (2010). Schedule Network Complexity versus Project Complexity. In: Tizani, W. (Ed) In Proceedings of the 13th International Conference on Computing in Civil and Building Engineering (ICCCBEXIII). The University of Nottingham, UK, Nottingham University Press.

Perminova, O., Gustafsson, M., & Wikstrom, K. (2008). Defining uncertainty in projects – a new perspective. *International Journal of Project Management*, *26*(1), 73-79.

Project Management Institute. (2000). *A guide to project management body of knowledge (PMBOK Guide)*. Newton Square: Project Management Institute

Osterwalder, A., & Pigneur, Y. (2009). *Business Model Generation,* Hoboken, N.J.: J. Wiley & Sons.

Remenyi, D., Williams, B., Money, A., & Swartz, E. (1998). *Doing Research in Business and Management*. London: SAGE.

Remington, K., & Pollack, J. (2007). *Tools for complex projects.* Hampshire: Gower Publishing Limited.

Rescher, N. (1998). *Complexity. A Philosophical Overview*. New Brunswick: Transaction publishers.

Ribbers, P.M.A. & Schoo, K.C. (2002). Program management and complexity of ERP implementations. *Engineering Management Journal,* 14 (2), 45-52.

Robson, C. (2002). *Real world research*. 2nd ed. Oxford, UK: Blackwell Publishing.

Rowlinson, S. M. (1988). *An Analysis of Factors Affecting Project Performance in Industrial Building.* Doctoral dissertation. Uxbridge: Brunel University.

Saunders, M., Lewis, P., & Thornhill, A. (2003). *Research Methods for Business Students.* 3rd edition. Harlow: Pearson Education Limited.

Saunders, M., Lewis, P., & Thornhill, A. (2009). *Research Methods for Business Students*. 5th edition. Harlow: Financial Times Prentice Hall.

Sambasivan, M., & Soon, Y.W. (2007). Causes and effects of delays in Malaysian construction industry. *International Journal of Project Management*, 25, 517–26.

Sanchez, L., Nunez-Nickel, M., & Gago-Rodriguez, S. (2010). The role played by interdependences in ERP implementations: An empirical analysis of critical factors that minimize elapsed time. *Information & Management*, 47, 87–95.

Schlindwein, S., & Ison, R. (2004). Human knowing and perceived complexity: implications for systems practice. *Emergence: Complexity & Organisation*, 6(3), 7-32.

Schutz, A. (1962). *Collected papers, I. The problem of social reality.* The Hague: Martinus Nijhof.

Shenhar, A.J, & Dvir, D. (1996). Toward a typological theory of project management. *Research Policy,* 25, 607-632.

Shenhar, A. J. (2001). One size does not fit all projects: exploring classical contingency domain. *Management Science,* 47(3), 394-414.

Shih, N.H. (2005). Estimating Completion-Time Distribution in Stochastic Activity Networks. *The Journal of the Operational Research Society*, 56 (6), 744-749.

Sinha, S., Thomson, A.I., & Kumar, B. (2001). A complexity index for the design process. *Proceedings of the International Conference on Engineering Design*, ICED'01, Glasgow, Vol. 1, Professional Engineering Publishing, Bury St Edmunds, 157-163.

Soja, P. (2008a). Examining the conditions of ERP implementations: lessons learnt from adopters. *Business Process Management Journal*, 14 (1), 105-123.

Soja, P. (2008b). Difficulties in Enterprise System Implementation in Emerging Economies: Insights from an Exploratory Study in Poland. *Information Technology for Development*, 14 (1), 31–51.

Tatikonda, M.V., & Rosenthal, S. R. (2000). Technology Novelty, Project Complexity, and Product Development Project Execution Success: A Deeper Look at Task Uncertainty in Product Innovation. *IEEE Transactions on Engineering Management*, 47 (1), 74-87.

Tavares, L.V. (1986) Stochastic planning and control of program budgeting – the model MACAO. In Coelho, J.D. & Tavares, L.V. (eds.), OR Models on Microcomputers, North-Holland, Amsterdam.

Tavares, L.V., Ferreira, A.J., & Coelho, J.S. (1999). The risk of delay of a project in terms of the morphology of its network. *European Journal of Operational Research*, 119, 510-537.

Tavares, L.V. (2002). A review of the contribution of Operational Research to Project Management. *European Journal of Operational Research*, 136, 1-18.

Tavares, L.V., Ferreira, A.J., & Coelho, J.S. (2004). A surrogate indicator of criticality for stochastic project networks. *International Transactions in Operational Research*, 11, 193-202.

Thomas, J., & Mengel, T. (2008). Preparing project managers to deal with complexity – Advanced project management education. *International Journal of Project Management*, *26* (3), 304-315.

Toor, S.-U.-R., & Ogunlana, S. (2008). Problems causing delays in major construction projects in Thailand. *Construction Management and Economics*, 26 (4), 395-408.

Turner, J.R., & Keegan, A. (1999). The Versatile Project-based Organization: Governance and Operational Control. *European Management Journal,* 17 (3), 296-309.

Turner, J.R. & Müller, R. (2003). On the nature of the project as a temporary organization. *International Journal of Project Management,* 21, 1-8.

Van Der Merwe, A.P. (2002). Project management and business development: integrating strategy, structure, processes and projects. *International Journal of Project Management,* 20 (5), 401-411.

Van Genuchten, M. (1991). Why is Software Late? An Empirical Study of Reasons For Delay in Software Development. *IEEE Transactions on Software Engineering*, 17 (6), 582-590.

Vanhoucke, M., Coelho, J., Debels, D., Maenhout, B., & Tavares, L.V. (2008). An evaluation of the adequacy of project network generators with systematically sampled networks. *European Journal of Operational Research*, 187, 511-524.

Venugopal, C. (2005). Single goal set: A new paradigm for IT megaproject success. *IEEE Software*, 22 (5), 48–53.

Vidal, L.-A., & Marle, F. (2008). Understanding project complexity: implications on project management. *Kybernetes*, *37*(8), 1094-1110.

Vidal, L.-A. (2009). *Thinking Project Management in the Age of Complexity. Particular Implications on Project Risk Management*. Doctoral dissertation. Paris: École Centrale des Arts et Manufactures

Vidal, L.-A., Marle, F., & Bocquet, J.-C. (2011). Measuring project complexity using the Analytic Hierarchy Process. *International Journal of Project Management*, 29, 718–727.

Williams, T.M. (1995). A classified bibliography of recent research relating to project risk management. *European Journal of Operational Research*, 85, 18-38.

Williams, T.M. (1999a). The need for new paradigms for complex projects. *International Journal of Project Management*, 17(5), 269-273.

Williams, T.M. (1999b). Towards realism in network simulation. *The International Journal of Management Science*, 27 (3), 305-314.

Williams, T.M. (2003). Assessing Extension of Time Delays on Major Projects. *International Journal of Project Management*, 21, 19–26.

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), 497–508.

Winter, M., Smith, C., Morris, P., & Cicmil, S. (2006). Directions for future research in project management: The main findings of a UK government-funded research network. *International Journal of Project Management*, 24(8), 638-649.

Winter, M., Andersen, E.S., Elvin, R., & Levene, R. (2006). Focusing on business projects as an area for future research: An exploratory discussion of four different perspectives. *International Journal of Project Management*, 24, 699–709.

Xia, W., & Lee, G. (2005). Complexity of Information Systems Development Projects: Conceptualization and Measurement Development. *Journal of Management Information Systems*, 22 (1), 45-83.

Xue, Y., Liang, H., Boulton, W.R., & Snyder, C.A. (2005). ERP implementation failures in China: Case studies with implications for ERP vendors. *International Journal of Production Economics*, 97, 279–295.

Yao, M.-J., & Chu, W.-M. (2007). A new approximation algorithm for obtaining the probability distribution function for project completion time. *Computers and Mathematics with Applications*, 54 (2), 282–295.

Yin, R. (1989). *Case study research: Design and methods*. Rev.edition. Newbury park, CA: Sage Publications.

Yin, R. (2003). *Case study research: Design and methods.* 3rd edition. London: Sage Publications.

Yin, R. (2009). *Case study research: Design and methods.* 4th edition. London: Sage Publications.

Zeng, J., An, M., & Smith, N.J. (2007). Application of a fuzzy based decision making methodology to construction project risk assessment. *International Journal of Project Management*, 25 (6), 589-600.

Umeå School of Business and Economics
Umeå University
SE-901 87 Umeå, Sweden
www.usbe.umu.se