BABEŞ-BOLYAI UNIVERSITY OF CLUJ-NAPOCA

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BUSINESS INFORMATION SYSTEMS DEPARTMENT

PhD. Thesis Summary

SOFTWARE DEVELOPMENT AND RISK MANAGEMENT IN COMPLEX PROJECTS

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Abstract

Using **knowledge** applied in the **business** environment, we **developed** a basic **framework** for risk management that is easy adaptable to different types of projects. This research **generates knowledge to solve real-life problems** in terms of projects implementation and compliance with deadlines. This work presents awarded **theories** from **Economics** and successfully **implemented** in **Informatics**.

A set of practices and standards for risk management helps **managing risks** during project lifecycle. The main approaches as **guides** or **standards** that offer **valid frameworks** to manage risks in complex projects are in continuous development and evolution. A proper risk management **plan** is recommended to **deliver** projects on predefined costs, time, and quality. Developing a tool for risk management involves a set of internal and external aspects. We present our **own framework** and **developed software**. Results from our internship are presented as the **collaboration** between the university and business environment.

Keywords: risk management, risk identification, risk mitigations, risk evaluation, software development, software development life cycle, traditional and agile methods, Reference Class Forecasting, implementation, organizational culture, group development

Contents

Introduction

By definition, project risks are uncertain events or conditions that, if occurs has a **negative** effect on project's objectives. Contrasting, **positive** uncertain events are called opportunities. More, risk management aims its practices to be tailored to the project and congruent with the organizational **culture**, **processes** and **assets**. Risks are unequally important, that's why it is very important to **filter** and **prioritize** risks for further attention. **Risk management** is essential to successful project management and aims to **identify** and **prioritize** risks in **advance** of their occurrence, and **provide** action-oriented information to project managers. This orientation [98] requires consideration of events that may or may not occur and are therefore described in terms of likelihood or probability of occurrence in addition to other dimensions such as their impact on objectives.

This work well **defines risk management** and its' **role** in a project lifecycle. Most often used standards and frameworks are identified and presented. After an identification of best practices for risk management we have adapted an existing standard and developed our own framework for risk management. Factors that may influence risk management integration in general project management plan are presented. Identified practices and factors are result of collaboration between university and business environment from our internship. We clearly **point methods** used in our software development project and main agile components to succeed. Based on this theoretical background we present our developed software solution. Throughout this work we give practical examples and own case studies.

In our research we were involved in a software development project for risk management. In the present paper is presented the architecture and developed software solution with relevant results. We consider that this approach fits customer requirements and provide significant results to avoid delays in projects by early identifying of risks to deliver projects in predefined costs, time and quality. A software application for risk management helps us to identify, mitigate, and evaluate risks in order to deliver projects in contractual terms and parameters without any penalties; delays in projects are not desirable. Choosing the best methodology for software development depends on several factors as project size and complexity, level of innovation, internal and external factors, available technology, organizational culture or project and team considerations. Agile software development methods are accepted worldwide as cost-effective and time-sensitive methodologies for software development in organizations to face the new challenges in this competitive environment. Adopting an agile approach produce higher-quality products designed to meet customer requirements in a better way and at a lower cost than in traditional approaches but to succeed is not enough to understand the agile approach. "*Changing practices is one thing; changing minds is quite another*" [38]. It is hard to become agile but it worth. We adopted an agile methodology for our research and project implementation. Our methodology is also focused on team building and task-oriented actions. Considering this, we take into account Scrum as best approach.

The objective of this thesis is **to identify, analyze and characterize** project risk management frameworks and standards and **to present and classify** traditional and agile software development approaches. Second, **it identifies and presents** theories behind Risk Management; we decide best approach in our research and point our **own opinions and contributions** in terms of **risk management** and **agile** methods. After a literature review, analyzes and studies we **build our own project risk management framework.** We also

present best practices for risk management and **describe our approach and software development** for risk management.

This thesis is structured in 4 main chapters. After a brief introduction, **Chapter 1** introduces project risk management aspects highlighting on its proactive aspect. Our main focus is on PMBOK Guide developed by Project Management Institute in a Practice Standard for Project Risk Management [95], [98]. Theories behind this research and adopted approach for Project Management based on our experience in the business environment are pointed. Best practices for risk management from our experiences are described. In **Chapter 2** we present the software development life cycle with traditional software development methods as Waterfall Approach [102], Prototyping Approach [113], Spiral Approach [24], Incremental Approach [77], and Rapid Application Development (RAD) Approach [82]. Following, we identified and listed the agile development approaches focusing on Extreme Programming (XP) [8] and Scrum [121], [105] and Capability Maturity Model Integration approach for development that helps organizations to achieve the project objectives by improving practices and measures the business and company maturity. Our focus is on work meetings and group development. In **Chapter 3** we present a **general valid framework** for project risk management highlighting that the presented framework is derived from condensing knowledge from industrial large projects; it is the result of collaboration between university and business environment. This chapter presents **our approach** and **our software developed** for risk management to succeed in risk identification phase and to reduce or avoid delays for future projects. As stated in [52], a main problem in major investment projects is a high incidence of cost overruns and benefit shortfalls caused by optimism bias and strategic misrepresentation in early project development. Finally, in **Chapter 4** we present our final remarks, our contributions and perspectives for future work in terms of risk management and software development.

Chapter 1

1. Risk management in software development projects

This chapter **provides** a complete **definition** of project risk and **its roots** with a clear presentation of risk management **approaches** and existing **standards** for project risk management. In our approach, a **complex project** is structured in **three main phases**: sales or acquisition, project execution or implementation and project closure and service preparation. In most cases, the execution team is distinct to the acquisition phase, reason why risk management should be **integrated part** in project management in every phase and in every process group. Starting with the definition, **risks** are **uncertain events** (Figure 1) which when occur have **negative effect** on at least one project goal – e.g., time, costs, contents or quality. Contrasting, the **positive** variability is desired and is called **opportunity**. Despite the simple explanation, the project managers often include into risks area the problems and technical or organizational issues. It is well to note: the risks are potential events in future which did not occur yet (while problems are risks that occurred). Risks are characterized by probability, always less than 100% and impact measured in changes of the objectives. Risks may be measured in **costs** (monetary risks) in **time** (delay risks for time management) or **quality** (usually affecting contracts thru monetary cost of improvement) [17]. Concerning risks in project management, a risk is considered to have at least one cause and at least one effect.

Figure 1 - Cause, Uncertain Event which is Risk if may produces an Effect

In a multidimensional space of the project objectives (or expectations), during project phases and based on the stakeholders evaluation, the project passes a trajectory [17]. Risk may be described as the **distance** between **the objectives** (or stakeholder expectations) and **the current situation** (or the perceived current situation) in the upper described multidimensional space. For this reason, targets require to be well defined, well known, and well documented for project. In the sales phase of projects, each large project crosses several phases that are relevant in terms of Project Risk Management (PRM). Risk management should be applied at major project milestones and hence be included in project plans and operational documents becoming integral part of every aspect of managing the project, in every phase and in every process group. Project Management Institute PMI® in the *PMBOK® (Project Management Body of Knowledge) Guide* – Fourth Edition defines Risk Management as processes concerned with conducting *identification* of risks, analysis of impact (*evaluation*), responses (*mitigation* process), and *monitoring & control* of risks.

1.1. Risk management standards

A number of companies and institutes have defined standards and methodologies for PRM. As well, a few authors identified some of them [109]; the most important are listed below:

- PMBOK Guide developed Project Management Institute [131];
- PRAM (Project Risk Analysis and Management) Guide [125];
- IRM Standard jointly developed by The Institute of Risk Management (IRM) [135];
- Australian and New Zealand Standard, AS/NZS 4360:2004 [136];
- PRINCE2 (PRojects IN Controlled Environments) methodology [132].

We consider that PRM activities and plans are developed and are the responsibility of all project stakeholders; this process continues throughout the project life cycle (PLC). In a software development project we need to clearly identify and define company preferences [69] to make the best choice and to propose the best solution. Any proposed solution, whether is hardware or software, need to integrate [22], [13] into company structure and to respect its policies. Tools and techniques for project risk management evolve while the principles have more stability and are more sustainable. A risk management approach is applicable throughout a project life cycle. The earlier in the project life cycle that a risk or risks are identified, the more realistic the project planning will be. Risk management continues to improve project evolution. Project planning progresses and more information becomes available. More unknown aspects become known.

1.2. Risk management theories in our approach

Our approach for Risk Management focuses on probability theory and makes a brief overview of **utility theory** [23], [62] and **prospect theory** [71], [72] as main roots and influences for risk management. As projects are unique in time and trajectory, another main aspect of risk management is the **uncertainty** which is inevitable in a project; from this reason, a **proactive** risk management is the key to succeed in complex projects. Based on **utility function**, milestones during project and/or the end of projects may be categorized in what are called

soft-deadline and **hard-deadline** [96]. Existing risk analysis methodologies observe risks from monetary terms. The typical risks are correlated with an increase in final project costs. In order to estimate hard-deadline milestones and/or end of projects or programme is critical to employ the time dimension rather than the typical cost-based risk analysis. Economists distinguish between cardinal utility and ordinal utility, the last being a rank-comparison of: options, contracts, projects, execution quality etc. In risk assessment activities, customer made already a decision that company "YZ" is executing the project. Therefore, the cardinal utility function over time is more appropriate, while ordinal utility may captures only **ranking** and not **strength** of preferences. Clear examples of projects with soft deadline are software development projects. In many cases a projects should be funded even if deadline expires because when it is finished still generates benefits. Contrasting situation which may be described as soft deadline, certain projects have hard deadlines. In more rigorous way, the concept of deadline is a time at which the value of the utility function falls to zero. A typical example of hard-deadline would be to build a stadium for future Olympic Games. If achieved weeks after the designed Olympic Games, the utility function drops to negative values represented by investment costs and loss at customer. The **prospect theory** was defined by Daniel Kahneman and Amos Tversky [71], [72] and is the basic theory in Reference Class Forecasting. Reference Class Forecasting for a particular project requires the following three steps [52]:

- *Identification of a relevant reference class of past, similar projects;*
- *Establishing a probability distribution for the selected reference class;*
- *Comparing the specific project with the reference class.*

Those theories, that helped Kahneman win the 2002 Nobel Prize in Economics, are based on some well-observed deviations from rationality.

1.3. Best practices for risk management

Based on the industrial practice, this chapter outlines strategies to identify, prioritize, and mitigate risks for achievement of project' or organizational objectives. Risk is typically represented based on probability vs. impact. Here is the summary of our recommendations where to look for sources of variability in risk management: event-risks which infers with the project; intrinsic variability in terms of costs/duration; correlations on events and variability; environmental changes during the project. Project risk management requires that all other management processes as planning, resource allocation, budgeting, to be performed at the level of the best practices available. Risk management adds the perspective of project risk to the outputs of those other processes and adds to their value by taking risk into consideration. For meaningful results it is imperative that risk management to be applicable throughout a project's life cycle.

Risk identification step: A risk cannot be managed unless it is first identified. The first step in the iterative project risk management aims to identify all knowable risk to project objectives. The fact that some risks are unknown or emergent requires the risk identification to be an iterative process. It is also important to achieve a full understanding of the present conditions in which the organization operates.

Mitigations: Risk management shall advise on strategies to manage the risk. Because the project manager is the owner of the risks in the project, he/she will decide on the method of mitigation and the priorities. When several risks are identified, each characterized by probability of occurrence and impact, the priority shall focus on the risks with high impact and high probability. After mitigation, in case the probability decrease the risks are represented on a lower as a parallel shift with y-axis; in the case the impact decrease, risks shift left (Figure 2).

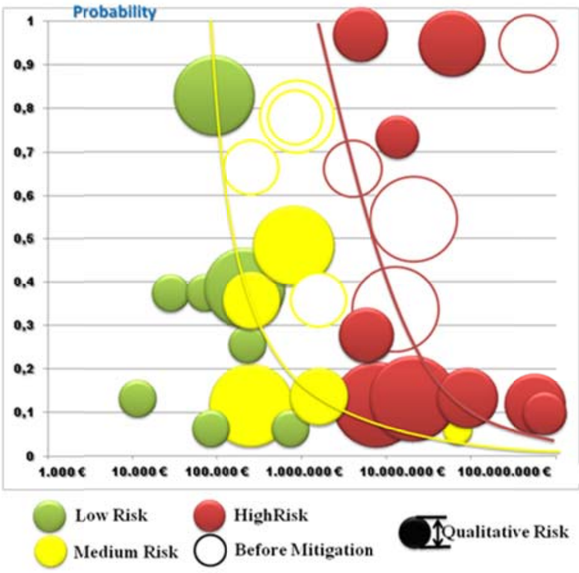


Figure 2 - Risk representation after mitigation

High risks are represented with red, medium risks with yellow and low risks with green in both situations: after and before risk mitigations.

Monitoring of risks: Changes in the business environment, completion of the project, will continue to affect the risk situation inside projects. This is the reason for performing the risk analysis not only once but in iterative cycles along major milestones or delivery baselines for the customer project.

1.4. Conclusions

Based on our experience in industrial field, we conclude that a risk management approach is essential to deliver projects in planned terms and deadlines. Any changes in the plan will involve financial or time investment. There can be no compromise to reduce the project quality for an on-time project in fixed costs. Current frameworks and standards exist to help in achieving specific project goals. Each project is unique and each situation should be analyzed to identify the optimal framework for risk management and how to use it. It can be used as it is or with minor or major customization level. In our case, we used Project Management Institute framework for complex projects adapted and customized for our field. We also consider that the human factor is essential for a project to be successfully completed. Project management structure and organize the project evolution and risk management identifies, mitigates and evaluates project risks. For a successful project, schedule, activities and rules must be respected.

As personal contributions, based on this classification and on identified standards for risk management and methods for software development we identified an approach that best fits our requirements. We also argued why selected solution is best and we have presented our results in several articles. Examples and case studies from our internship were presented to support our approach. We presented our conception about complex projects and explained phases from our project for software development in risk management department. Software development methodologies and best approach in our case will be detailed in Chapter 2. We identified main steps to succeed in identifying, prioritizing, and mitigating of risks for achievement of project' or organizational objectives. Based on these steps we'll build our framework for risk management in Chapter 3.

Chapter 2

2. Agile software development and team building for on-time projects

Software development is a complex process to create software **starting** from a specific set of **requirements**. It involves **teamwork** and a lot of **communication** with a major positive effect in terms of innovation. Recent studies for software development focus on methodologies and analyze developers and users satisfaction in software development projects [119], studies that have important implications for managers *trying to balance the challenges of managing new software development and making enhancements to existing software, while engaging the user actively in the software development processes.* This chapter **describes the software development life cycle** and **identifies traditional and agile development methodologies** in this field. All these methodologies respect the development life cycle. Existing ones propose a set of methods and steps with different frameworks to develop a valid software product to meet customer requirements. In this chapter are **listed traditional** software development methods and their **evolution** to **agile** development methods. From our perspective, best approach for software development for risk management is an agile method as **uncertainty** is omnipresent in any project.

2.1. Software development life cycle and methods

The **software development life cycle** (SDLC) process is defined as an organized way involving multiple stages. The process starts with determining **customer needs** and **user requirements** and ends with **maintenance**, **documentation** and personnel **training** if necessary. It also includes a way to use **feedback** for continuous improvement of the development processes. Adapted after [128], we have defined and structured **steps** in the software development life cycle.

A software development method refers to the used **framework** for **planning** and **controlling** the **process** of developing a software application. In traditional software development methods are included: **Waterfall** Approach [102], **Prototyping** Approach [113], **Spiral** Approach [24], **Incremental** Approach [77], and Rapid Application Development (**RAD**) Approach [82]. Choosing the best approach for a Software Development Project depends on the project type and context, internal and external environment, technical specifications, organizational features and policies.

Changes in business and technology environments force software developers to adapt and find new solutions for successful projects and software development performance. Recent literature presents studies that analyze agile development approach and combine qualitative and quantitative data analyses for process performance in terms of on-time completion, on-budget completion, and software functionality [78]. The term of agile software development (ASD) was introduced in 2001 by Agile Manifesto [124] and describes *a methodology where requirements and solutions evolve through collaboration between cross-functional teams*. During the software development project, user requirements can change dramatically and require software development in an agile and flexible environment; this is an efficient and effective approach comparing with traditional software development. The most popular methods for ASD are: Extreme Programming (XP) [8] and Scrum [121], [105]. Our main focus in on Scrum process that is described in three phases as pointed in [1], [105]: *Pre-game, Development* and *Post-game.* All defined roles are defined to ensure an optimal process development. Both methods focus on team communication and collaboration with small team size (less than ten-twenty persons). Roles are clearly defined for maximum efficiency and work productivity. In practice, both methods are widespread.

Our main interests are in software development projects, risk management and team building. In next sections we also present aspects from our experience in software development projects. Main interests are focused on work meetings and group dynamic/evolution. In their research paper [94], authors perform studies on how CMMI (Capability Maturity Model Integration) could be used in assessing agile software development or in a situation in which the organization is planning to change its processes towards agility. We are interested in CMMI for Development as our objective is to deliver software development projects in predefined contractual parameters as costs, time and quality.

2.2. Team building in achieving project goal

Scrum approach as agile development highlights on simplicity of the product and of the project. It focuses on sprint meetings to help the team understand what must be done. As several authors agree [93], in sprint planning meeting the *product owner helps the team to plan its work and commit to a sprint goal, thereby laying the foundation for its self-organization. The team figures out how much can be done and how to do it.* We consider that team building is a decisive factor in order to succeed in software development projects. An agile approach is mandatory to meet requirements that change over the project life cycle. Besides team training, group development is essential to produce innovative ideas and to deliver projects in contractual terms and deadlines.

The stages of Group development are best described in Bruce W. Tuckman's article [103], in which he synthesized about 50 articles on different type of group formation**.** For the proposed stages the author proposed following terms: *forming, storming, norming* and *performing*. Regarding the first stage, we consider that it identifies each member qualities and how those qualities may be used in accomplishing the projects' overall objective. Achieving the objective involves tasks and resource allocation to each team member based on their previous experiences. If it is possible, lesson learned reports should be considered in order to avoid repeating a same mistake twice. Each member' previous experience can influence the project evolution and implementation. This stage is characterized by little work and a variable amount of emotionality, during which the members are concerned with defining the directions the group will pursue. In this stage interpersonal problems are taken care of with dependence, while task problems are met with task-oriented behavior. Orientation, testing and dependence constitute the group process defined as *forming*. Our opinion is that in the second stage each member expresses his own opinion and ideas regarding the project, roles and task allocation. Please note that this stage is dominated by complaints and conflicts well designed to avoid future communication problems in the team. The communication gaps between the members will only be filled in the next stage where communication will become more efficient. Third stage has been labeled as *norming*. From our approach, this stage generates final roles and norms that helps flourish, tensions has been eliminated within the group and the members can now focus more efficiently on the task at hand. The communication boundaries have been passed and each member can now express freely own ideas with no fear of being judged in case of a mistake. The fourth developmental phase of group structure is known as functional role-relatedness and named *performing*. In our case, performing is by far the most efficient stage, concerning the task, here results are visible, and the members are task oriented with few interpersonal conflicts. Each member is allocated to the task where it has maximum efficiency and in case he finishes his task before the deadline he may assist his team mates on their parallel tasks or on non-depending tasks from their project management plan. All team members are focused to deliver the project in contractual terms.

In terms of a conflict, we agree that a task oriented conflict produce benefits that helps a project to grow and generates new and innovative ideas and approaches. Opposite, a member oriented conflict is not project productive and may obstruct the completion of the performed task or may generate negative impact on project overall objective.

2.3. Conclusions

We consider that collaborating in sprint meetings is essential in a software development project using agile methods. A team building period and team accommodation with the project and with the product they need to develop is a first important step. Those meetings are design to fill the collaboration gaps between team members and to clear point what each member done, what each member has to do until next meeting. In this way, potential risks are identified and things that can go wrong respecting project initial plan and schedule. Agile software development methods can easily be integrated with project management for a correct project plan, task allocation and resource planning. Our opinion is that group development is a mandatory feature in the project life cycle and evolution. An individual can obtain benefits from the group as the group can obtain benefits from each individual, previous experience of each team member combined in teamwork may produce better results with less effort when performed individually, and this is particularly useful in complex projects. Interrelations within the group help the members to develop new skills and abilities or to improve the existing ones. Besides company culture oriented on agile methods, human factor and group dynamic is very important, reason why team building must guarantee that no communication gaps or any constraints exist. The real challenge arises in the collision between the company culture and policy, project team members and agile. *Agile methodologies such as Scrum create transparency. Every deficiency that obstructs the best flow of work is singled out for examination* [73]. Regarding our contributions in this chapter, we can mention that we have pointed our software development project features and provided practical case studies and examples. Each phase from a software development life cycle project is defined and referred by an own perspective. We clearly listed and detailed traditional and agile development methods highlighting the benefits of communication in meetings and group development.

Chapter 3

3. Our approach and results

Based on identified standards listed in **Chapter 1** we have selected PMI standard as best approach and in this chapter we present our **own framework** in first sections of this chapter. This chapter also presents our software development project using **agile methods** and respecting development life cycle described in **Chapter 2**. The objective of this chapter is to present **our proposition for a general valid framework** (Figure 3) for project risk management. As well, we focus to the minimum set of knowledge that may manage different types of projects. **Developed software solution and implementation** is also presented. We consider that this approach fits customer requirements and provide significant results to avoid delays in projects by early identifying of risks. This chapter presents our methods and our software developed for risk management to succeed in risk identification phase to reduce or avoid delays for future projects. Throughout the paper we'll give practical examples from our experience in software development and risk management.

3.1. Steps for risk management framework

The presented framework is derived from condensing knowledge from industrial large projects. Risk management is the systematic process of identifying, analyzing, and responding to project risks [95]. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to project objective. Risk management is essential and helps to avoid additional costs, delays or poor quality in project implementation. An integrated risk management plan in general project management plan helps to manage risk in projects' uncertain environment.

3.1.1. Need for this approach

Risk is defined as a possible future event that, if it occurs, will lead to an undesirable outcome [79]. It refers to the loss itself, but as well to possibility of loss, or any characteristic, object, or action that is associated with that possibility [74]. Essentially, risk is the effect of uncertainty on objectives [99]. The purpose of project risk management [40] is to minimize risks of not achieving the objectives of the project, while taking advantage of opportunities. The objectives derive from consulting stakeholders. At beginning and during project life cycle is important to know the requests; then filter, rank, transform and communicate stakeholder's requirements. In particular, risk management assists project manager's decision making. It directly influences costs, budget and resources allocation, and decisions related to mitigation, insurances – generally setting priorities. There is a thin border between risk management and a proper project/program management. The two aim successful projects. While project management is the integrator and defines the large and detailed picture, the risk management looks at projects as being the path and its deviation into the n-dimensional space of constraints. It aims to ensure that threats to the projects are identified, analyzed and appropriate strategies are undertaken to mitigate and control risks [86].

Using knowledge applied in industry, we propose basic steps for risk management easy adaptable to different types of projects. We collect techniques for risk identification step and present best approaches for early risk identification. The aim of current framework for project risk management is to actively manage risks in business context and to deliver projects according to signed contracts and deadlines. In a generic project, risk management efforts shall be proportionate with the possible impact of the project. There is a distinction between project execution costs and the impact of the project. A simple example would be a small project that may affect the population in the region. Based on maturity where the projects run, a set of management processes are defined.

3.1.2. Proposed and implemented framework

Starting from PMI guidance for project risk management we identified few steps and we proposed and implemented a customized framework. The current framework for project risk management was successfully integrated in project management plans and implemented in complex projects to identify potential risks in the project life cycle. This framework was developed during our internship where we helped the specialized Project and Risk Management department to identify, mitigate and evaluate risks in projects. Risk management is easier applied into an organization that has established a project and risk management oriented culture. The simple framework for risk management is divided in four main steps.

Risk identification step: consists in a set of techniques and tools used to clearly identify risks. There is a difference between risks, problems, and unknown solution. Unknown solution is not necessarily risk, it is an activity that shall be planned and budgeted. Occurred risks are problems and risk management shall treat them apart. The Risk identification step is influenced by the business environment, the company culture, and stakeholder's knowledge. We may think of three categories of risks: known risks, risks we know we don't know, and finally risks we don't know we don't know. Thinking to these, we recommend the set of techniques from [40], [98]. In addition, other methodologies and techniques may increase the success of identification step, but in the case of small and medium types of projects proper risk identification may be achieved by Brainstorming sessions, Check lists, Interviews, Lesson Learned Reports, Questionnaire, SWOT Analysis. It is very important to perform a risk management process during whole project life cycle. New risks may arise or ignored one may become active.

Risk assessment and evaluation: the simplest way to rank risks is to visualize them based on risk probability and risk impact. One may employ a set of tools or software solutions that may help with the visualization and with the identification step. The project manager or the risk manager prioritizes risks to offer action-oriented solutions. Managers employ results from qualitative and/or quantitative analysis to evaluate the likelihood of success in achieving project individual and overall objectives. The analysis addresses individual risks descriptively and focuses on risks with greatest effect on overall project objective. Quantitative analysis refers to methods when the team may correctly estimate risk (e.g., measured in currency, time) based on existing knowledge, i.e., the probability of occurrence multiplied with the impact of the respective risk. When quantitative measures are not possible, the team may rank (e.g., in 3 categories as minor, medium, major) the respective risks in terms of manageability vs. capability to predict risk size. This is called qualitative analysis. Risks with low manageability and high predictability may get easier insured. For high manageability risks managers may define actions. High manageability risks and high predictability risk shall be re-assessed and defined in quantitative terms of impact vs. probability.

Third phase of framework is **risk mitigations step**. We analyze options and assign corresponding costs and efforts to identified risks. A cost/benefit analysis is mandatory to decide if measures will be taken or not. In this step we can decide to avoid a risk by not performing the task/activity that may produce the risk. There are 3 useful approaches that prioritize risks. Certainly, higher the risks (in terms of probability x impact) shall be mitigated first. In addition, there are a number of low-hanging fruits, meaning risks to which the mitigation cost is insignificant. The third is to view the risk in terms of root-cause analysis. Risks may group since it may have a common root cause. It is very important to assign costs and efforts for the mitigation of each risk. This solution is useful when tasks that may produce risks can be avoided or replaced by similar one that may not affect the project objectives. Aside of avoidance or mitigation strategy, the last aimed to reduce the negative impact of a risk on a project objective or on project overall objective, one may look to transfer the risk to a third party (e.g., to buy insurance for transport, or simply to outsource the respective part of the project). Not all identified risks can be managed or mitigated. In some cases we have to accept the risk. There shall be an evaluation made of the conditions under which a risk will be accepted and two different methods of making this evaluation are, as well pointed and identified in [85]: *Cost/Benefit Considerations* and *Living with the Possible Consequences*. Accepting a threat or an opportunity strategy applies when the other strategies are not considered applicable or feasible. Acceptance entails taking no action unless the risk actually occurs, in which case contingency or fallback plans may be developed ahead of time, to be implemented if the risk presents itself [98]. This is the place where some managers introduce so called "plan B" as a continuation when the risk occurs. This is not mitigation of original risk, but helps for re-planning and is usually less costly than starting to plan the "plan B" when the risk occurs.

Fourth step of our framework is **risk and mitigation monitoring**. Once the managers decide on certain actions (called mitigations) that address the risks, it may take long until the actions are fruitful. An example would be a risk related to miss-communication. Any decision will not decrease the risk immediately; it may take months until communication channels are effective. On monitoring step, managers shall actively appraise the decisions, the effectiveness of taken action. More, during the project life cycle, new risks can arise or risks may close because the project passes over respective phases. Therefore review process shall be part of the regular management plan and that action plans are implemented and progressed effectively [40]. Developed framework for risk management (Figure 3) clearly identifies main steps in this type of planning. It offers solutions and traces to successful apply this iterative and proactive process. It is a real and used solution to manage risk in a project uncertain environment.

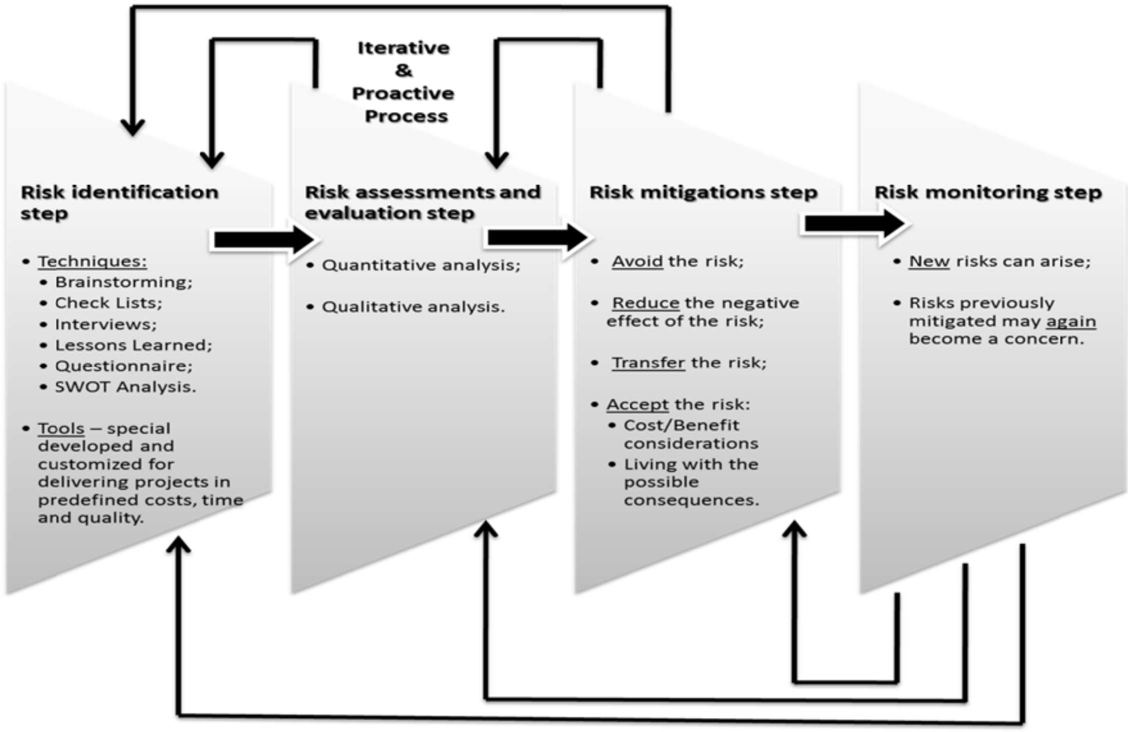


Figure 3 - Minimal framework for Project Risk Management

The simple steps discussed in this chapter are a reduction to the minimum of much larger and much complex steps applied in management of large and complex industrial projects.

3.2. Software implementation

In this chapter we present our application and software development method, pointing the graphical user interface design for our software solution and our approach for using reference class forecasting in real business environment in complex projects from energy and financial sectors. As we previous pointed, early risk identification enables key project decisions to take maximum account of risks inherent to the project. We are interested in finding most relevant features for a project, to classify projects "delayed" or "on-time" and to forecast a new project based on our past experiences. Scrum methodology fits best our software development project in an environment where unpredictable is expected. Every task in Scrum is carried out through sprints and meetings where each team member state what did since last project meeting, what will do until next project meeting and define if there are any obstacles.

3.2.1. Conceptual background for developed software solution

Considering a set of similar projects run by the same department (e.g., a company that executes alike projects or constructs similar developments), above a typical risk analysis that is due in each project, it is essential to know features that correlate to delay-risks. The project features may be technical, project management related features, country specific features, or economic environmental characteristics. Also, it is desired to better estimate the milestones or the end of the project. To evaluate delay-risk in complex or large projects, one method is to granularly build activities and link in the Gantt diagrams; evaluate the expected risks in each activity and further probabilistic build the expectance at milestones or end of the project. Such complex projects may deal with thousands of activities that are packed in dozens work-packages (e.g., the electrical section, civil engineering, cabling and piping, gas turbine, or the heat recovery steam generator). This method may be biased because of the cumulative complexity of linked activities. More, the risks one may initially assess are not independent; delay-risk at one activity may have a common root-cause and generate further delay-risks on the entire project. Kahneman and Tversky [71], [72] describe that human judgment is generally optimistic due to overconfidence and insufficient consideration of complexity. Based on competition, execution companies are under pressure to propose shorter terms and lower prices, sometimes unrealistic from planning. In this context, reference class forecasting [72] proposes to use distributional information from previous projects similar to the one being forecast. This is called taking an "outside view". Although the method is simplistic compared with the probabilistic-build version of the expectance at milestones based on granular expectations of each activity, it may better cover complexity and correlated risk. Further, the American Planning Association (APA) endorsed reference class forecasting *"APA encourages planners to use reference class forecasting in addition to traditional methods as a way to improve accuracy."* The reference class forecasting is relatively difficult to implement in practice. Based on mathematical kernel density estimate, reference class forecasting depends dramatically on the reference class. The bias is stronger when the class is small. Slightly different, an alternative nonparametric method is called *k*-nearest neighbors or *k*-NN. It is similar to kernel methods with a random and variable bandwidth. The idea is to base estimation on a fixed number of projects - observations *k* which are closest to the desired project. A classical feature selection step helps in characterizing the projects. Therefore, we are interested in finding most relevant features for a project, to classify projects "delayed" or "on-time" and to forecast a new project based on our past experiences.

3.2.2. Developed software solution and results

K–nearest neighbor algorithm (k-NN) is a machine learning algorithm used for classifying objects. Basics of *k*-NN are described in [50], [117] and [84]. *K*-NN rule proceeds as follows to classify a project profile: a) Find the closest k observations in the learning (training) set and b) Predict the class of the "unknown" project profile by majority of vote (the winning label of the neighbors).

Our architecture is based on model-view-controller (**MVC**) model; the essential purpose of model-view-controller model is to bridge the gap between the human user's mental model and the digital model of computers (Figure 4). Our approach required the knowledge and the binding of a large number of programming languages for solving particular problems than a general purpose language. The **View** component was implemented in Macromedia Flash, XForms, PHP and CSS and assured a company look and feel product that runs as a web application designed to imitate a desktop application in order explore graphical capabilities without a look-in of the application's business logic. The **Controller** component was implemented in XQuery, which is a query and functional programming language that is designed to query collections of XML data. Query language such as XQuery requires considerable efforts when they address the problem of efficient processing of XQueries in single-user relational environment [97] where the queries are formulated using a user-friendly Graphical User Interface. For this component, we also used Java and JavaScript and the algorithm was developed in Matlab® from MathWorks [129]. For the **Model** component we used a Tomcat server and eXist-db which consists in an XML native data base, required for data storage and management. A main advantage of MVC solution is to assure a high modularity and further avoid time consuming customization or minor / major adjustments.

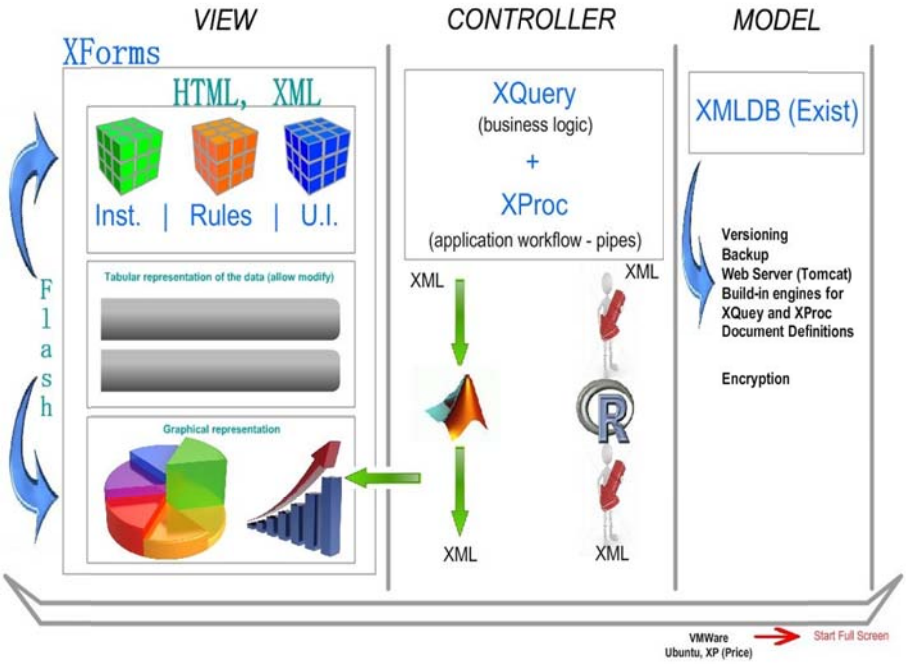


Figure 4 - Our generalized architecture proposal

MVC solution allows that part of the model can be modified or replaced without changing other parts. In first tests of the application, different modules can be used and then link them in the final application and members of the development team were able to work in parallel tasks. We developed client side and server side in different tasks and weekly meetings were also planned to link components and parts of the application. In requirements engineering, there is a clear distinction between the "request" and "requirement". Requests are technical wishes that generally are not validated. Based on various stakeholders, each of stakeholders may generate a number of requests that may or may not intersect or conflict with the requests of other stakeholder. Collecting all requests as a common basis of understanding the developments and the stakeholders is a positive technique. Contrasting, requirements are assumed, validated and accepted specifications by the project, typically decided by project / product management. In our case, project members participated in defining, review and specification of the requirements. An initial set of requirements were defined during development as element-part of agile software development. New requirements were tuned to increase the customer satisfaction, generate more impact and lower costs. Each new requirement was evaluated based on its new functionalities that may bring and criticality to the success of the project implementation and the product development. Only requirements that reflected real customer needs were accepted as our main interest was to develop a high usability and well-ordered product. For our tests we used a dataset structured as in Table 1 (Characteristic is marked as "*Char*" and a value as *project number* x *characteristic*) and application state machine diagram is presented in Figure 5. Results were also presented in one of our works [19]. Proposed architecture was accepted and validated by project and risk management department. Components and responsibilities of MVC modules were clearly presented according to company internal rules and policies. Part of external software needed for development was open source and covers all development phases.

Table 1 - Dataset structure

Project Name	Char_1	Char_2	...	Char_N
Name_1	1x1	1x2	...	1xN
Name_2	2x1	2x2	...	2xN
...	...	...	...	...
Name_M	Mx1	Mx2	...	MxN

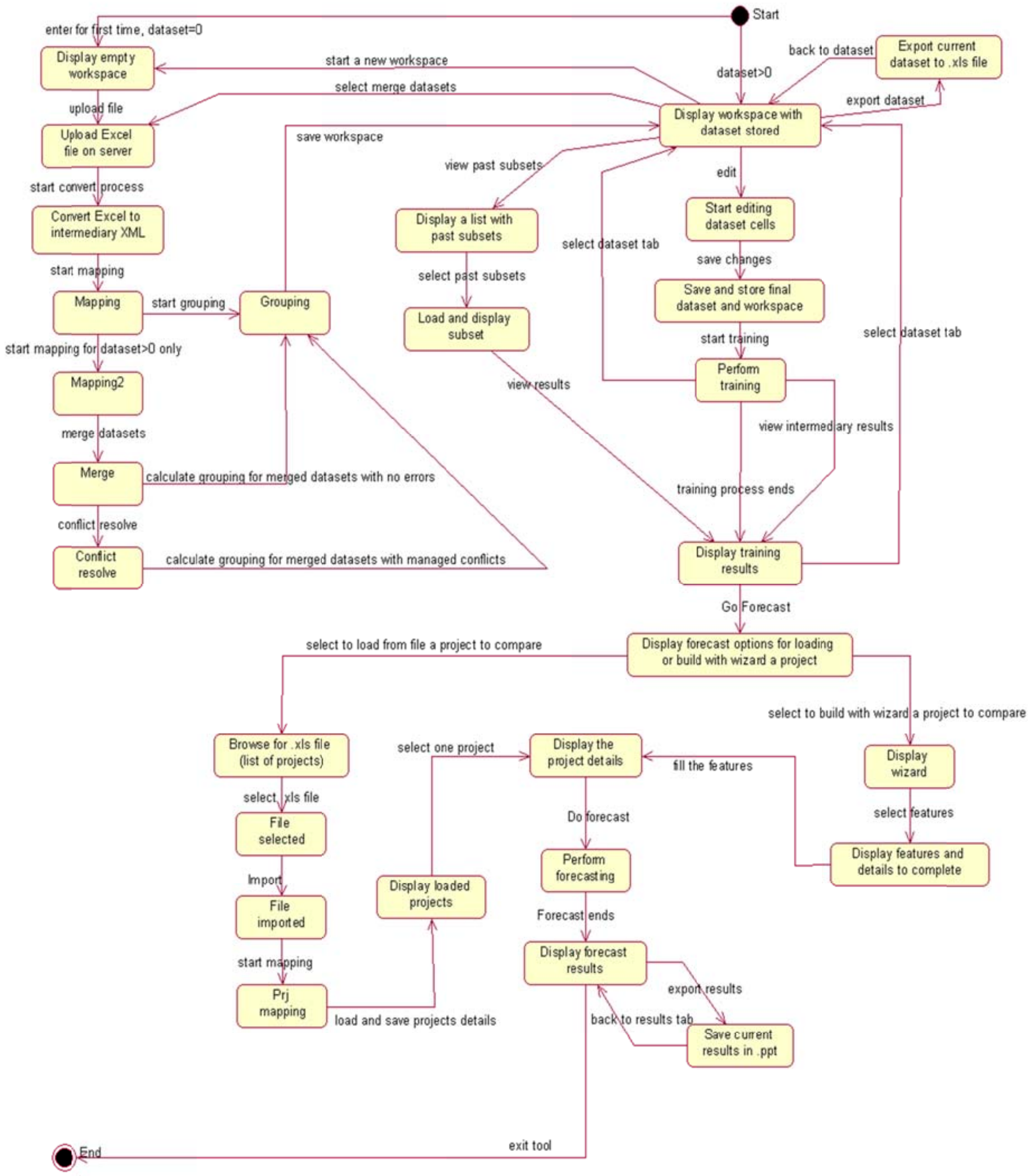


Figure 5 - State machine diagram for the application

This application focuses on modularity and on a high level of customization; all application modules are independent one from another. In this way we offered an efficient solution for further improvements. For example a modification in import step will not influence the design or implementation of other steps. It also true that computers should support virtualization for this solution. We offered our solution in VM, in this way any host station with a VM Player installed can load and run the machine and the application with minimum effort. First, a virtual machine was created and used on multiple computers. This is a platform independent solution; developed software is enclosure in VM and can run on any system. We also used this solution for backup; last VM was saved on a department shared drive when new modules were developed. To browse for files on local drive (e.g. stored in Windows and accessed from Linux) we need to define a shared folder and to store files in defined location. In our case, shared folder is defined on local drive. Our software solution is structured in 4 main steps: data preparation, data analyze, results and forecast. This work highlights the methodology used for this type of analysis and the results step. Developed application makes retrospective assessment of project delays based on past experience and solves two basic types of problems: the dataset training with results visualization and a new project prognosis. In practice, input for this program will come from an Excel file, and results from this program will be exported as an Excel file for dataset or as a PowerPoint presentation for training and forecast results. It is also likely that the program will run many times as the design is refined. Application behavior is detailed described in previous state machine diagram and will be step by step described in next sections. In all scenarios, user should spend a sufficient time for data preparation, including filtering, editing and/or grouping. Before the training process starts, data must be checked and cleaned because this is the recommended way for more accurate training results and then a better project prognosis. Result of an analysis depends by data input relevance, rightness and precision.

Dividing the application in main steps was useful to assure a high modularity and to ease further improvements or modifications. Tests were performed on each module and a selected module can run independently. The application runs as a web application that acts as a desktop one. For example, even if a pop-up window is defined in a case, it won't be a new window because it is embedded in Flash. Action Script code defined in Flash Actions permits multiple visible/hide windows. In this way, user will never leave the application process or main window. Pop-up window content is stored in external file. This also was a preferred solution for further minor modifications; there is no need to modify Action Scrip code from Flash; only external files should be edited to apply a modification. GUI simulation was performed according to main state machine diagram and main noted use cases. Main application steps are described in the following paragraphs. Each step is explained and detailed according to main state machine diagram (Figure 5) previously presented and steps in our software solution. We also considered necessary an export step to offer solutions for data store in Excel files and for results store in PowerPoint presentations. State machine diagram is depicted in main steps and each step is explained in compliance with identified use cases. A freeze of design task presented in our general project management plan was defined as a major milestone in our software development project. A set of quality gates were also defined in project management plan after each step implementation to assure that application respects all requirements (initial requirements and new accepted requirements during implementation process).

In **data preparation** step we are able to import files with details about projects characterized by a set of features and the class-label value, in our case the delay value. This module is developed to store and handle these files and to offer valid solutions in terms of clean editing and data preparation for training process. Selected file is converted in XML format and displayed in web interface. Application runs and last loaded data set is displayed. This is in case of no first time run. Otherwise, no data set is displayed and workspace is empty. When new data set needs to be imported a browse option is activated. Considering that application runs in UNIX, a mount option is necessary if we want to load data from external USB. On server side, selected file is converted in XML format and stored in eXist-db. Next step is mapping, user must select type (Number, Text or Date) for each header of imported data set; application automatically identifies type of the field but in case of Blank identification field type must be corrected. Each field needs to be defined as text, number or date. Blank fields should not be defined. After field mapping, we can create groups and data set is displayed in editor with afferent groups. A data set versioning is also stored with performed modifications. Grouping step is necessary if we want to create multiple groups and to perform different training. For example, we performed trainings on groups with technical characteristics and with financial features stored in same data set and Excel file. Editor respects Excel file aspect and allows minor data modifications, similar with Excel editor; it intends to avoid potential errors (e.g. data is represented in different formats, a name is written in different ways John Doe is not similar with Doe J. even if it refers to same person). Text fields can be edited and to lists we can add or remove elements, number fields allow only number values and date fields allow picking a date from a calendar in our defined format yyyy-mm-dd. Editor displays data with fixed header and scroll content and also permits data sort, ascending and descending, by any fields of the data set. For this section we used a set of JavaScript functions for interactive tables and CSS for view model and classes (numeric, default, currency and date) for each header field.

In **data analyze** step, the application runs and trains to learn the most relevant features from past projects and to predict uncompleted or “unknown” projects. Before training process starts a parameters selection is needed. For our analysis we considered to set number of random assessments and number of neighbors. As we presented in our MVC architecture, in view module we used Macromedia Flash with ActionScript and PHP. Source of flash file is generated and .swf file is embedded as object in classic html code with no margins and exactfit. In Flash, for each parameter we designed a different scene to draw and place objects.

In **results** step, after selection for number of random assessments and maximum number of neighbors, training is performed; after performing training, all relevant graphics are displayed. Intermediary results are displayed to offer real time output of the application. Initially, a box-plot representation is displayed. A wrapper approach means to select individual features and combinatory sub-set of features. Box plots represent five aspects of error rates obtained by random selection of project in train set, learn and then apply the k-NN classifier on test set: the minimum error, lower quartile (the 25-percentile), median in red line (the 50-percentile), upper quartile the (75-percentile), and maximum. This type of analyzes is preferred because data can be quickly compared and results are relevant. Points outside the ends are outliers. Features that generate compact box plots with lower median and a low error classification are important for our analysis. A small box-plot means that respective characteristic (feature, or combination of features) participate to the error rate consistent over the projects in the set. Low median of error rates are beneficial for characterizing respective set of projects. Features that generate error rates around the 0.5 are random, and not useful for classification. Based on these analyses, relevant features (characteristic) are identified and selected for next representations. Our approach improves the existing reference class forecasting methodology by introducing a feature selection learning step and the use of k – Nearest Neighbor (NN) density estimation, which is based on a variant of nearest neighbor density estimation of the group-conditional densities. For our tests when using singular features, the classification error is calculated over a number of iterations. Data are divided in test and train with a proportion of 1/3 for the test and 2/3 for train. The box-plots (in Figure 6) present the distribution of the error classification per feature. A few characteristics used for project identification (as project code, internal rank, classifications etc.) were ignored because are not relevant for this type of analysis (and being unique generate a narrow distribution centered on 0.5). These types of characteristics are used in data preparation step to verify that a project is unique and data is not duplicated.

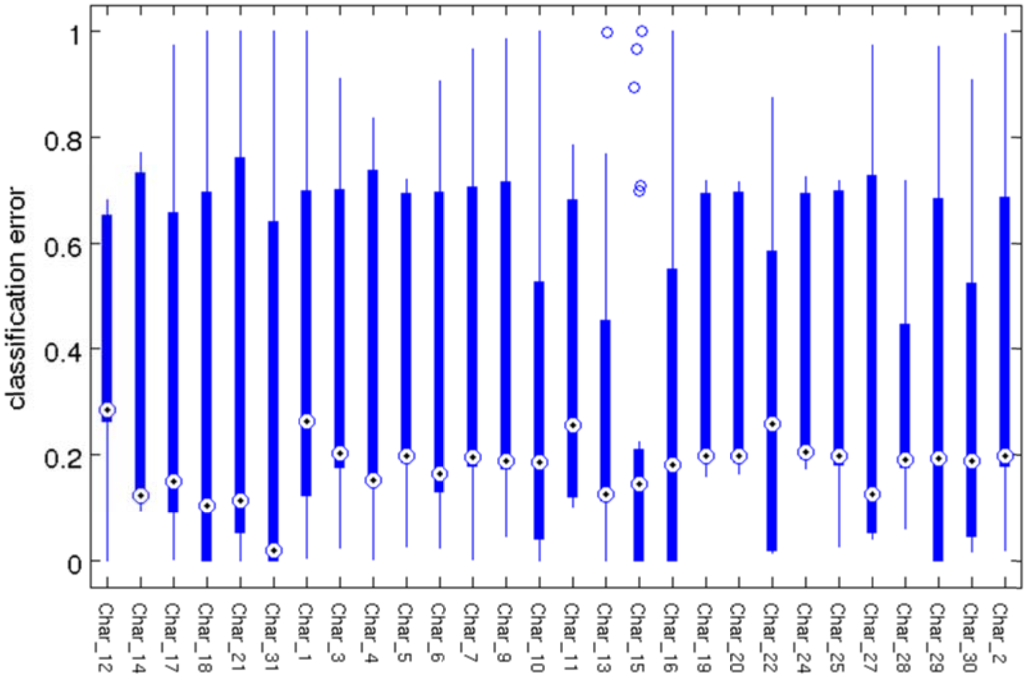


Figure 6 - Conceptual classification errors for a set of relevant characteristics

Characteristics (in Figure 6 denoted as "*Chars_*") may be considered alone or in combinations. Once a characteristic generates a good correlation with the outcome (in this case delay) the combinations of characteristics that contain the respective winning characteristic are better only if lower the error rate beyond the single option. In Figure 6, particular to the simulated case, relevant singular feature is *Char_31*, because has a specific lower median than the other features. We may say that is *Char_31* correlates with the delays in the projects. By using the same concept we test combinations of 2 pairs of all the features and generate the combinatory $n!/((n–k)!\ k!)$ columns, where n is the total number of features and k is the combinations. In the practical case the system was tested, we used a set of approx. 100 projects, each project characterized with a number of approx. 75 features. As features we used details about customers, suppliers, type of technology used, number and type of components, dates for contracts, kickoff point, delivery time, technical complexity and risk features and financial details. Projects were structured in small projects where the contract value less than one hundred millions, medium projects with contract value between one hundred millions and three hundreds millions and big projects with contract value more than three hundreds millions. Relevant features are those that generate **a lower classification error**, yield **a lower median** and are represented in a **compact box-plot**. Once the relevant features are selected (Figure 7), we may visualize the projects grouped using the dissimilarity matrix, hierarchical clustering or multidimensional scaling representation.

Figure 7 shows a new analysis on a new dataset to exemplify feature selection step and how most relevant features are identified. All analyzed features are represented in this analysis and listed for selection. Relevant features in this case are marked by a circle in previous figure and generate a good correlation with the outcome. This selection helps to generate further graphics. Selected options are stored in a text file. Each feature is defined by a number and selection is defined by 1 if selected and by 0 if not selected.

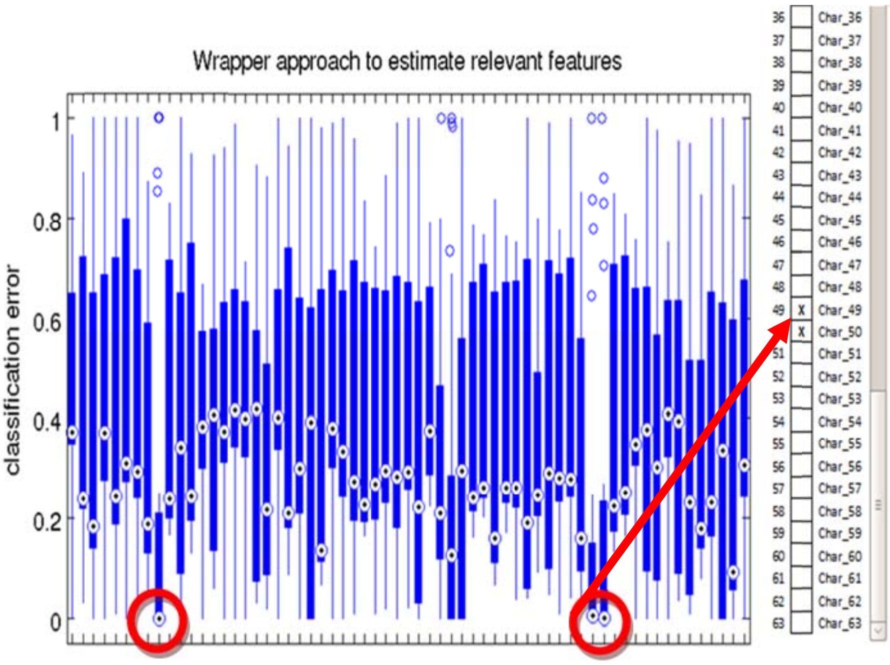


Figure 7 - Select relevant features to generate further graphics

Next figures are generated according to relevant features identified in box-plot analysis and then selected. Projects may get grouped using dissimilarity matrix (Figure 8) and hierarchical clustering (Figure 9), where the distance between each two projects is based on the selected features in the previous step.

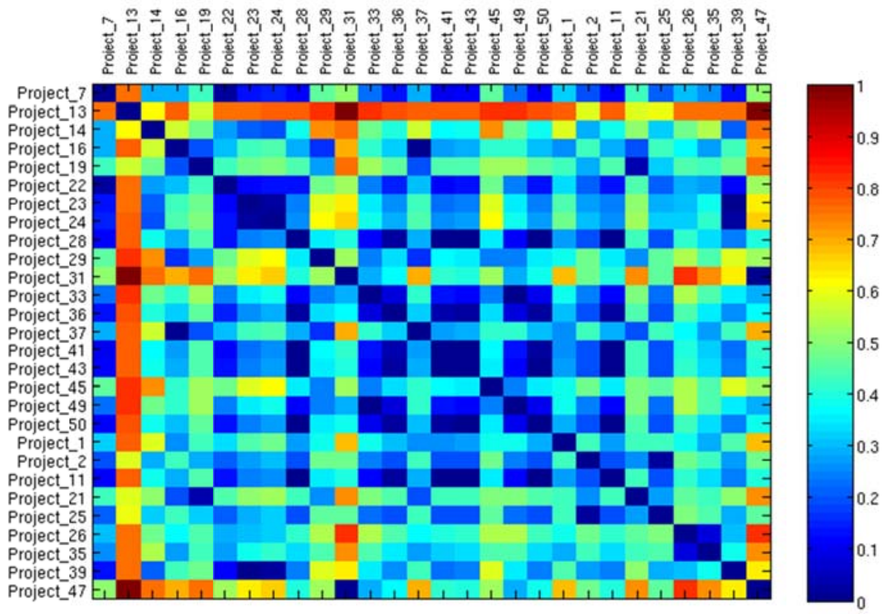


Figure 8 - Dissimilarity matrix

In our case, dissimilarity matrix (dissimilarity = 1 - similarity) displays the distance between each two projects based on an M x M matrix. For example, Project_50 is similar with Project_50 because is one and the same project (similarity is 1 and dissimilarity is 0). We are interested in similar projects to be able to group them. For a better representation, a hierarchical clustering is displayed where projects are ordered and ranked.

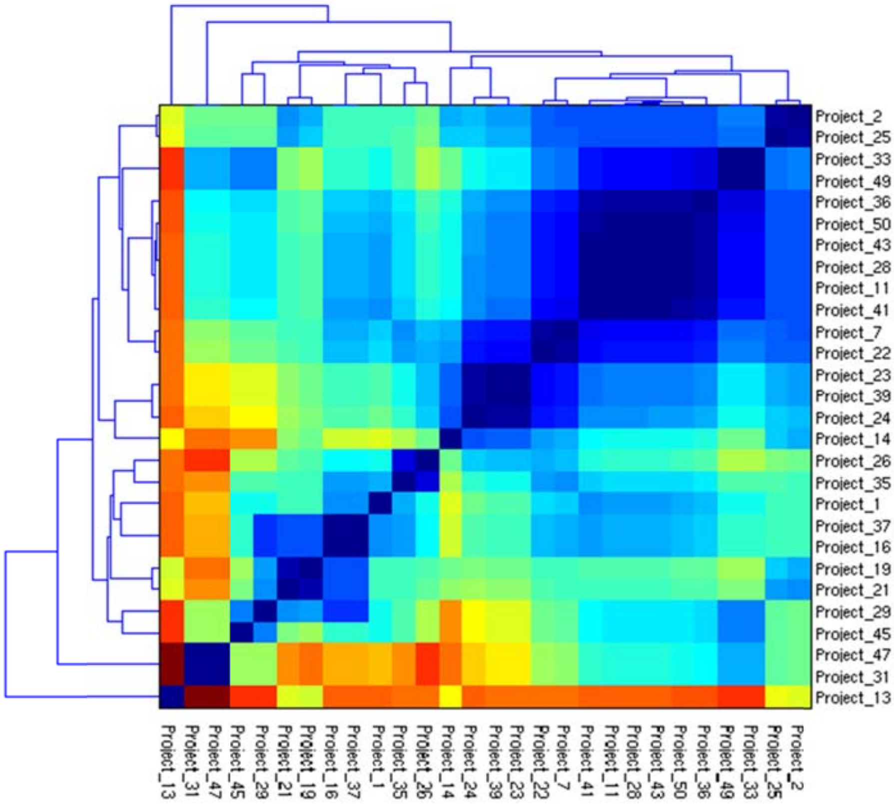


Figure 9 - Hierarchical clustering representation of similar projects

Another way to represent current project, when projects are characterized by multiple features, is to scatter the "delayed" and "on-time" projects using a multidimensional scaling (MDS) technique. MDS (Figure 10) is a special type of ordination and a typical statistical technique to visualize similarities or dissimilarities in our trained data set.

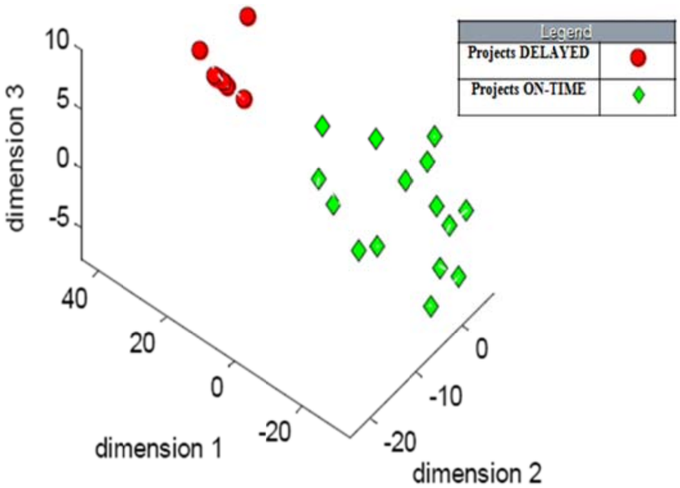
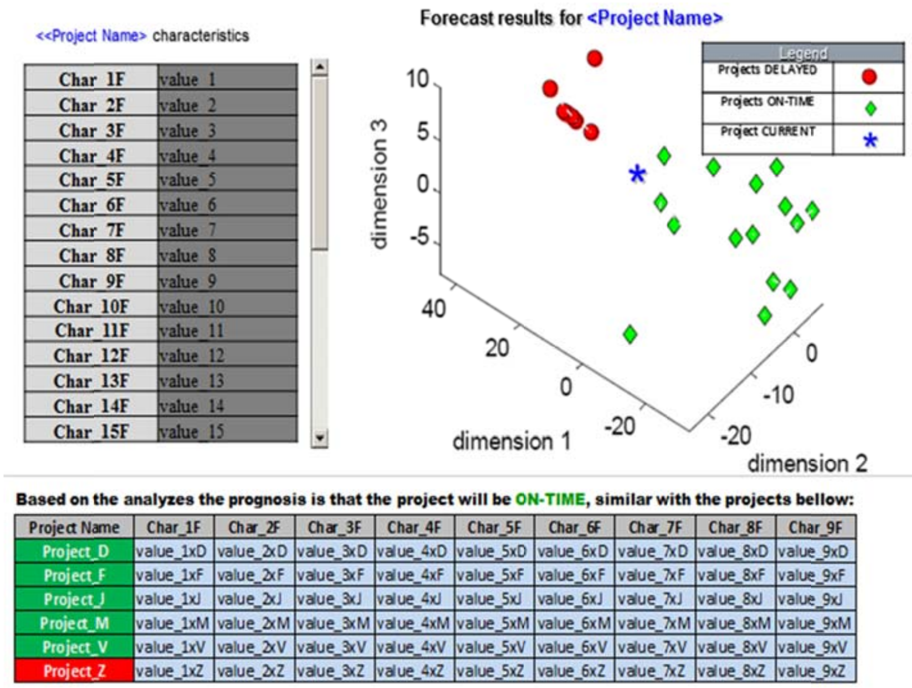


Figure 10 - Multidimensional scaling representation

Forecast step allows predicting a new project and to position it in closest observation group identified after training step. In this step a prognosis if a project will be delayed or not is made, based on past experience and training. A data set with projects for forecasting is loaded by importing from an Excel file or using a wizard (a wizard will guide the user step by step to complete the features and the values for the features). Import procedure is similar with import procedure from data preparation pointing that only one project can be selected from the list for forecast. The analysis displays graphically and as a table the forecast results. A list of similar projects is displayed and the estimation if the project will be or not delayed (Figure 11).



Char_1F	value_1
Char_2F	value_2
Char_3F	value_3
Char_4F	value_4
Char_5F	value_5
Char_6F	value_6
Char_7F	value_7
Char_8F	value_8
Char_9F	value_9
Char_10F	value_10
Char_11F	value_11
Char_12F	value_12
Char_13F	value_13
Char_14F	value_14
Char_15F	value_15

Project Name	Char_1F	Char_2F	Char_3F	Char_4F	Char_5F	Char_6F	Char_7F	Char_8F	Char_9F
Project_D	value_1xD	value_2xD	value_3xD	value_4xD	value_5xD	value_6xD	value_7xD	value_8xD	value_9xD
Project_F	value_1xF	value_2xF	value_3xF	value_4xF	value_5xF	value_6xF	value_7xF	value_8xF	value_9xF
Project_J	value_1xJ	value_2xJ	value_3xJ	value_4xJ	value_5xJ	value_6xJ	value_7xJ	value_8xJ	value_9xJ
Project_M	value_1xM	value_2xM	value_3xM	value_4xM	value_5xM	value_6xM	value_7xM	value_8xM	value_9xM
Project_V	value_1xV	value_2xV	value_3xV	value_4xV	value_5xV	value_6xV	value_7xV	value_8xV	value_9xV
Project_Z	value_1xZ	value_2xZ	value_3xZ	value_4xZ	value_5xZ	value_6xZ	value_7xZ	value_8xZ	value_9xZ

Figure 11 - Forecast GUI using a demo data set

For a particular new project, that belongs to the same (economic) environment, our reference class forecasting application identifies the closest observations in the training set and predicts the class of the selected new project profile. Training set is composed from projects with high percentage of completion (typically >80%). Based on the existing model from training, most similar projects with the new project are ranked and listed, as well as the 3-D space of multidimensional scale representation. Based on delays features, a new project can be positioned on closest class. Multidimensional Scaling representation may depict the projects: e.g., the green we may represent projects that occurred on time while with red there are projects that had delays. The blue star is our current project. The class of the "unknown" new project (blue star in our representation) profile is predicted by majority of votes, the winning label of the neighbors. The two representation methods, hierarchical clustering and multidimensional scaling representation bring similar projects in view, allowing program managers to easier predict issues in the planning. More, it underlines the features that leaded to the respective similarity. These features are equally related to better timing in the projects or worse delays.

An **export** solution was also integrated and allows exporting workspace and results. This export option is necessary to export final dataset for last version, to consolidate, to have last version of file or to have a clean data set. Graphics (collective classification-boxplots, dissimilarity matrix, hierarchical clustering and MDS) are also exported to be used in a presentation and to be presented to customers as result of our analysis. We consider that our application is well developed to estimate delays in complex projects and is relevant to any corporation with large and complex projects. We also defined a set of documents for user documentation. We defined a document with **user interface specification** where we explained basic goals of the application and common scenarios, an overview of the application and step by step graphical user interface visualization. In **requirements document** we have presented some aspects concerning scope of the software, product perspective, product functions, main graphical user interface requirements, operational environments and user characteristics. **Technical specifications** document describes the proposed model-view-controller architecture and its benefits. **Help** file provides assistance for our software solution use. During the execution of an analysis we also provided information and guidance for a correct use, help file can be accessed from any step of the application.

3.3. Conclusions

Proposed own framework for project risk management **can be applied** to different types of projects as is or with minor customizations. While each project is unique in terms of objectives, business environment, requirements or stakeholders – proposed risk management framework can be adapted to any field and can easily be integrated in project management plan. In **risk identification** step we have presented **a set of techniques** that can succeed in early risk identification, in risk mitigation phase strategies to manage risk are presented. We also pointed features for risk evaluation. The **framework is derived** from complex projects as the minimum set of requirements. Although simpler, it follows the essential steps of main standards and approaches for risk management. We show a **particular implementation** and the **software developed** for risk management focused on reference class forecasting. The reference class forecasting approach aims to reduce bias and strategic misrepresentation. The theoretical work around reference class forecasting helped Kahneman win the Nobel Prize in Economics in 2002. **Starting** from reference class forecasting theory **we have implemented** and used a modified algorithm in real business environment by **adding** an intermediary step of features selection.

Chapter 4

4. Final remarks and future work

For successful projects and for risks control in projects **we discussed** about ***risk management*** and **described** the current concerns in this domain. We **identified standards, rules and conceptual frameworks**. Important **research** conducted in the area was **presented** in an educational manner. An **overview** of **traditional and agile software development** methods **was made** and the associated **frameworks** were **identified** to develop a useful application for risk management. Project risk management provides benefits when it is implemented according to good practice principles and with organizational commitment to taking the decisions and performing actions in an open manner. **Risk management** shall be **integrated** part of **project management** in every phase and in every process group. Included in project management plan, a risk management applied at major project milestones will provide more realistic paths and easily manage risks in projects' uncertain environment and life cycle.

Based on PMBOK Guide framework, **we identified** all necessary **steps** in our software development project **and presented our own framework** for risk management. Our **proposed framework proved its efficiency** in our projects and managed risks in complex projects. It can be adapted and easily integrated in project management plan for any type of projects. Presented techniques and strategies can be useful and assure project' delivery in deadlines.

Although we had some challenging tasks during the project life cycle, we consider this **agile approach** a relevant evolution of our research. Initial analysis helps to plan better at the start of the project. A proper risk management plan integrated in general project management plan also supports a **higher quality** and **lower cost** products. **Project risk management** is an **essential** and determinant step towards **successful** projects. All real risks that can affect one or more objectives of the project must be identified and managed. A detailed analysis and a precise definition of risk can lead to successful achievement of objectives.

Company policy and culture is an essential factor. A risk management oriented culture is desirable. Human factor is also a decisive factor in our main approaches, in development projects and risk management processes. We consider that Scrum as agile approach is a continuous improvement process. **Collaboration** in **sprint meetings** and **group development** are crucial factors in adopting agile methods. Collaboration gaps between team members need to be filled and each team member is aware by his task until a next sprint meeting. An analysis is mandatory for project plan development for a proper integration in company policy and culture and to avoid potential intern problems. In this initial analysis can be identified major aspects that can dramatically change the project trajectory and implementation strategy.

A software application for risk management helps team members to identify features that influence the quality or costs or cause delays in projects. It needs to do a clear priority of risks mitigation, to prioritize and identify high risks with low awareness or low risk with high awareness in an effective and efficient way. Bad experiences make the next project more expensive. We consider that agile development methods are preferred when a team decides to implement a software solution. Some of those methods share many benefits and common features but some of them are more focused than others. Traditional solutions and methodologies for software development are not used in the real software development environment.

In software development life cycle, initial software requirements may suffer major changes. Developers must consider those changes to achieve customers' needs. From this point of view, an agile software development method is indicated and capable to solve all the problems. An agile software development approach is useful to satisfy customer needs that are changing during the software development process according to their principle for high-quality and low-cost products or services; it is also an active approach for financial benefits and to achieve company goals. We consider our research topic a new one, relevant and with major impact for successful projects. By research, science aims to generate knowledge to solve theoretical and/or practical problems and we managed to do this.

4.1. Personal contributions

Identified standards in terms of risk management were **adapted** to **build** our **own project risk management framework**. Developed framework was **applied** in business environment in our agile software development project. Based on theories from Economics we managed to implement them in a real solution in Informatics.

As relevant results for this research, we have **developed and implemented a complex software solution** that helps to find the closest k observations in the learning (training) set and to predict the class of the "unknown" project profile by majority of vote (the winning label of the neighbors). This method helps to avoid delays in complex projects. As we defined, in our case, a complex project is structured in three phases: a) sales or acquisition, b) project execution or implementation, and c) project closure and service preparation. Risk management should be integrated in project management plan and our proposed framework assured a correct approach to manage risks in projects. This reference class forecasting approach aims to reduce and eliminate optimism bias and strategic misrepresentation. Reference class forecasting based on ideas of decision making under uncertainty has won the Nobel Prize in Economics 2002. Our approach improves the existing methodology by introducing a feature selection learning step; it improves the original reference class forecasting and helps program managers to point towards essential features that are correlated with time risk management. Based on past experience and training and according to selected relevant features projects may get grouped and a new "unknown" project is positioned in the closest observation group.

We have developed a complex application for risk management using reference class forecasting. It is well designed to fit in the company structure and behavior. It is a powerful application with high portability level that learns from past experience and prognosis current or future projects, it provides an easy editor and functions for data manipulation, provides an complex dictionary data validations against typos and terms written in different languages, provides a complex versioning, field mapping and filtering solution. The Graphical User Interface respects company internal standards and policy; it provides step by step guide through the application and is easy to use, user do not see or understand the Matlab® algorithms behind. The application workflow was defined and presented and the results of your work are immediately visible and reported in an educational manner; results representation and graphs were defined and approved by company Project and Risk Management department. This approach and our developed application proved to be useful in real business environment and best risk management practices adapted after Project Management Institute standards [98] led us to successful risk management and project delivery respecting all contractual terms without any penalties or financial loss.

As author's bibliography shows, we were interested in several topics. We published research articles in several international conferences and journals as results of our work in PN2 grants as PN2_IDEI 2359, 936/2009 (Business Process Management) and PN2 no. 92-100/2008 SICOMAP (Collaborative systems for management of economic projects). Another result is our published risk management chapter in the monograph of PN2 no. 91-049/2007 (Intelligent Systems for Economic Decision Support) grant. We also consider our experience in group development and managerial meetings an essential aspect for our career.

4.2. Directions for future work

As for our future work, we intend to **apply** our risk management framework in POSDRU projects to avoid problems in implementation. In this way we can identify potential problems that may radically influence the project and the budged by reallocating funds. Our framework was successful **integrated** in complex projects in our internship. We plan to present our approach in several projects managed by our faculty as POSDRU/87/1.3/S/63908 (ECON) Project and POSDRU/87/1.3/S/63909 (RLNM) Project. We also plan to develop a more complex project management plan for mentioned projects and to **provide** a methodology for projects' meetings. We also intend to measure faculty maturity and capability to implement projects and to attract European funds. Regarding our application, we want to **optimize** the Graphical User Interface to fit new requirements and preferences, to refine and optimize the code for better performance and faster analyze in training and forecast steps, to compile and integrate code for combinations of features analysis, to optimize export procedure to store datasets and groups for each dataset in files in initial formatted style, to refine documentation where necessary and to define and implement restrictions for normal users and advanced users. After a set of relevant projects and identified features we will be able to **apply** our reference class forecasting methods.

4.3. Author's bibliography

I. Books

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