ANALYZING PERFORMANCE OF ENGINEERING PROJECTS BY EARNED VALUE METHOD

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SARA BILALI

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

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Bilali, Sara

M.Sc., Department of Civil Engineering

Supervisor: Assoc. Prof. Dr. Elfrida Shehu

It has been accepted in project management industry that time, costs and quality are the main factors that affect the success of an engineering project. If these parameters are completed within predicted specifications, then the project is considered as successful. A lot of engineering projects don't fulfill these parameters and continue to fail. The purpose of this thesis is to analyze the performance of engineering projects through the process of monitoring and controlling. This is done by implementing an advanced model that calculates their performance, the Earned Value Method. This method gives an overall project performance in the terms of schedule, budget and quality by calculating its performance indexes. Calculation of performance indexes, is done not only by calculating them in the terms of schedule and costs in the present, but also by calculating them for the future, by calculating forecasting indexes and future performance indexes. This helps to undertake corrective actions in the implementation of engineering projects in the future.

Keywords: Earned Value Method; Control; Monitoring; Construction Management; Performance Indexes; Engineering Projects.

ABSTRAKT

VLERESIMI I PERFORMANCES TE PROJEKTEVE INXHINIERIKE NEPERMJET METODES SE VLERES TE FITUAR

Bilali, Sara

Master Shkencor, Departamenti i Inxhinierisë së Ndërtimit

Udhëheqësi: Prof. Asoc. Dr. Elfrida Shehu

Eshtë një fakt i pranuar në industrinë e menaxhimit të projekteve që koha, kostot, dhe cilësia janë faktorët kryesorë që ndikojnë në suksesin e një projekti inxhinierik. Nëse këta parametra janë përfunduar sipas specifikimeve të parashikuara, atëherë projekti inxhinierik konsiderohet si i suksesshëm. Shumë projekte inxhinierike nuk i përmbushin këto parametra dhe vazhdojnë të dështojnë. Qëllimi i kësaj teme është të analizojë përformancen e projekteve inxhinierike nëpërmjet proceseve të monitorimit dhe kontrollit. Kjo bëhet duke aplikuar Metodën e Vlerës së Fituar. Kjo metodë jep një përformancë të përgjithshme të projektit duke u bazuar në kosto, afate, dhe cilësi, duke llogaritur indikatorët e tyre të performancës. Llogaritja e indikatorëve të performancës bëhet jo vetëm duke i llogaritur ato në bazë të kostove dhe afateve në të tashmen, por gjithashtu duke i llogaritur ato për të ardhmen, duke llogaritur indikatorët parashikues dhe indikatorët e performancës së ardhshme. Kjo ndihmon që të ndërmerren veprime korigjuese në zbatimin e projekteve inxhinierike në të ardhmen.

Fjalët kyçe: Metoda e Vlerës së Fituar; Kontroll; Monitorim; Menaxhim Ndërtimi; Indikatorët e Performancës; Projekte Inxhinierike.

…Dedicated to my big family…

I love you all dearly.

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LIST OF ABBREVIATIONS

PMBOK	Project Management Body of Knowledge
PMI	Project Management Institute
W	Physical Advancement of the whole Project
EVM	Earned Value Method
EV	Earned Value
PV	Planned Value
AC	Actual Cost
CV	Cost Variance
SV	Schedule Variance
CPI	Cost Performance Index
SPI	Schedule Performance Index
EAC	Estimation at Completion
BAC	Budget at Completion
ETC	Estimation to Complete
CPI_{future}	Future Cost Performance Index
SPI_{future}	Future Schedule Performance Index
WBS	Work Breakdown Structure
OBS	Organizational Breakdown Structure
CPM	Critical Path Method
PERT	Program Evaluation and Review Technique

CHAPTER 1

INTRODUCTION

1.1 Introduction

Project success is one of the most important concepts in project management, but also it doesn’t have a clear definition because project success means different thing to different people. The iron triangle is considered for so many years as a measure of project success. The relationship between time, cost and quality is such that they are so close to each other that a change in one reflects in change on the other.

In the construction project, time and cost are the most important factors to be considered in the planning of every project. The aim of project is to finish the projects on time, within budget and to achieve the quality. It is a difficult task undertaken by project managers in practice. Despite the years of individual and corporate experience of managing projects and despite the fact that many projects meet the three constraints, project results continue to fail.

What can be done to minimize the failure of engineering projects? How can the performance of these projects be measured in order to have less failures and more engineering projects with good performance based on technical and economic terms?

In this thesis, it is represented an analysis of the performance of engineering projects by implementing the processes of monitoring and controlling. The physical advancement of the project is calculated and the Earned Value Method is implemented. These two methods measure the performance of engineering projects in the terms of schedule, costs and quality. EVM is a method that serves to minimize the failure of engineering projects and it can make possible to undertake necessary corrections to the future performance in order to improve its performance.

1.2 Why choosing this Topic

It is important to choose this topic because studying the main factors that affect the performance of construction projects, and especially the relationship between three main factors: cost-time-quality can help to improve the performance of engineering projects. Every project has these three parameters and are interdependent: it's impossible to change an element without conditioning at least one of the other two.

This topic can offer a solution for engineering projects to improve their general performance by implementing the Earned Value Method. The control of the performance of engineering projects can be done by keeping the three parameters, budget, schedule and quality in control, by implementing EVM. Through this thesis it is shown that by implementing EVM it is possible to undertake corrective actions in the future that will serve for improving of the performance of engineering projects.

This topic offers a lot of new information and data from which can also benefit a broader audience and also can be valuable for Albanian construction industry, because it offers the utilization of the best international methods of management and control of engineering projects.

1.3 Aim and Novelty of the Study

The goal of this study is to analyze the overall performance of engineering projects in the terms of schedule, cost and quality. The method that is chosen to do the analysis of the engineering projects performance is the Earned Value Method

(EVM). Earned Value Method measures the three key success factors, budget, schedule, and quality, in engineering projects. This method can also give solutions of how to improve an engineering project's main performance by calculating its forecasting indexes and also by calculating its future performance indexes.

1.4 Research Question

In this research there are a lot of questions asked and a lot of answers that are expected to found. Some of the thesis questions are: What are the basis of a project success? What is the role of time, cost and quality in a project and how are they related to one another? What is a way that a project can calculate and analyze its general performance? How can its performance be improved?

The main question of the thesis is: How can we measure the performance of engineering projects? This is also the goal of this study.

1.5 Organization of this study in chapters

This research is organized into five main chapters.

CHAPTER I: Introduction – The first chapter includes the introduction part. It contains some basic information about the topic and it is divided into five main parts: Introduction, Why choosing this topic, Purpose and Methodology used, Research Question, and Organization of this study in chapters.

CHAPTER II: Literature Review - In this part is going to be the theoretical part of the thesis. The literature review portion gives essential background on the topic and familiarizes the reader with what has already been written on the topic. The theoretical framework is divided into six main parts: Key concepts about project management, Project success criteria, Key success factors that affect the performance of construction projects, Budget-scope-schedule triangle, and the Performance of engineering projects through the processes of monitoring and controlling.

CHAPTER III: Methodology – This part explains the methods used in this study and the case study data. It is divided into three main parts that are: Calculation of the advancement of the project, Calculation of Earned Value Method and Data and specifications of the project, where are the specifications and data of the chosen projects are explained.

CHAPTER IV: Results and Discussion – All the results from this study are obtained and discussed. Meaning of the results is interpreted. The results are given for the calculation of performance indexes according to costs and schedule of a completed engineering project. The ongoing project is interpreted in three main parts such as calculation of performance indexes according to plan and schedule, calculation of forecasting indexes, calculation of final change of schedule and also calculation of future performance indexes.

CHAPTER V: Conclusions – This part includes the conclusions and recommendations for the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Key concepts about Project Management

Project Management is a wide field that has a lot of different concepts, and deals with all the phases of implementing a project, such as: engineering aspect, logistics, and construction aspects, both in technical and economic aspects. In this section there are included some main key concepts that the field of project management includes such as: project, management, and project management.

2.1.1 Project

By definition a project is an endeavor that is undertaken to produce the results that are expected from the requested party. In other words, it is an undertaking to achieve specific objectives in a certain time. A project consists of three main components that is going to be the main discussion of this study: scope, budget and schedule [Oberlender, 2000].

The project always has a start and an end. The project may be a building, bridge, dam, pipeline, sewage treatment plant, water supply system, or any other numerous types of projects. The project participants may be three or two if it is considered the concept of design-build contracts: the owner, designer and builder or the owner and the design-builder [Fisk & Reynolds, 2006].

There are many types of projects, such as the following:

- Creative projects: painting a picture, writing a book, etc. The main characteristic of this type of project is that the participant needs satisfaction.
- Rule-book projects: inspecting materials in a construction work, financial auditing, etc. The main characteristic of this type of project is that rules of conduct exist and these may be interpreted to the benefit or detriment of the project.
- Team projects: designing and constructing a chemical plant. Main characteristic of this type of project is that a diverse range of high-level skills and training may be required to contribute to the execution of the project.
- Task projects: building houses, military operations, etc. Main characteristic of this type of project is that physical work is involved [O'Neill, 1989].

Some example on how these projects are managed is described below in the table.

Table 1. Project Types and Key Management Styles [O'Neill, 1989]

Project Type	**Key Management Style**
Creative	Encouraging
Rule-book	Applying rules effectively
Team	Directing, team leadership
Task	Commanding, asserting authority

2.1.2 Management

Management can be broadly defined as 'the control of the resources'. The basic task of management is: Planning, Measurement and Control. Planning is the first step of this process and it sets out the work to be done so that the operations can begin. After the time is specified in the plan and the amount of work satisfactorily completed is measured, then the actual work done is compared with the plan. Measurement comprises counting or measures by some means the amount of work completed in the time period. Also, control of some form has to be exerted by making a change to what is being done. The first thing to determine is the reason for the difference between the plan and what has been achieved, and this may lead immediately to the cause of the difference and the action necessary to correct it [Woodward, 1997].

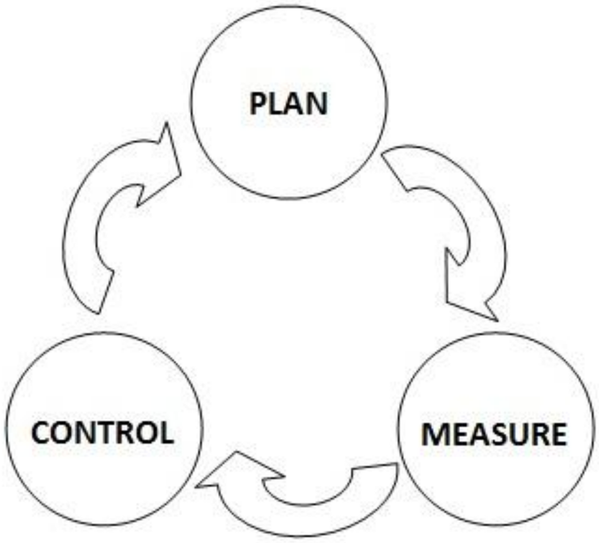

Figure 1. Model of plan-measure-control cycle [Woodward, 1997]

Management can be summarized into five basic functions: planning, organizing, staffing, directing and controlling [Oberlender, 2000]. The same rules apply for project management also.

- Planning: the formulation of a course of action to guide a project to completion.
- Organizing: the arrangement of resources in a systematic manner to fit the project plan.
- Staffing: the selection of individuals who have the expertise to produce the work.
- Directing: the guidance of the work required to complete a project.
- Controlling: the establishment of a system to measure, report and forecast deviations in the project scope, budget and schedule [Oberlender, 2000].

2.1.3 Project Management

Project management may be generally defined as ‘the control of the resources in a temporary arrangement to achieve project objectives’. The control of the project depends crucially upon the understanding how time, money and other resources are related to one another and how they can interact in order to achieve the required project results and objectives [O’Neill, 1989].

> *‘At its most fundamental project management is about getting things done,’*
>
> Dr Martin Barnes

The British Standard defines Project management like this: “the planning, monitoring and control of all aspects of a project and the motivation of all those involved in it to achieve the project objectives on time and to the specified cost, quality and performance”. [British Standard Publication, 2010].

The key components of project management are:

- Defining the reason why a project is necessary;
- Capturing the project requirements, estimating resources and timescales, specifying quality of the deliverables;
- Preparing a business case to justify the investment;
- Securing corporate agreement and funding;
- Developing and implementing a management plan for the project;
- Lending and motivating the project delivery team;
- Managing the risks, issues and changes on the project;
- Monitoring progress against plan;
- Managing the project budget;
- Maintaining communications with stakeholders and the project organization;
- Provider management;

- Closing the project in a controlled fashion when appropriate [APM, 2010].

According to Lou Russell the 10 steps to a successful project management are:

1. Decide if you have a real project to manage (Is it a project?)
2. Prove your project is worth your time (Why do it?)
3. Manage scope creed
4. Identify, rate and manage risks (Risk mitigation)
5. Collaborate successfully (Seek first to collaborate)
6. Gather your team and make a schedule (Build a schedule)
7. Adjust your schedule (Monitoring the project)
8. Embrace the natural chaos of people (Negotiation and conflict)
9. Know when you're done (Ending well)
10. Embrace the natural chaos of people (Review and learn) [Russell, 2007].

2.2 Project success criteria

Project success is an important concept of project management, but it does not have a clear definition because researchers rarely agree. Project success means different things to different people. It is a concept that means so much to so many people because of varying perceptions and also leads to disagreements about whether a project is successful or not [Liu & Walker, 1998].

Success criteria are "measures by which success or failure of a project or business will be judged". Project success criteria consists of two main components: product success and project management success. Product Success deals with the effects of the project's final product and it has three main criteria: meeting the project owner's strategic organizational objectives (goal); satisfy users' needs (purpose); satisfy stakeholders where they relate to the product (primarily costumer/user).

Project Management Success focuses upon the project process and it has three main criteria: meeting time, cost and quality objectives; quality of the project management success; satisfy stakeholders during project management process [Baccarini, 1999].

According to Baccarini project management success and product success are related to each other in these ways and has these main characteristics:

- *Project Management Success is subordinate to Product* Success – The project management success criteria of time, cost and quality are subordinate to the higher product success objectives of goal and purpose. A project that is considered as a project management failure can be perceived as a product success.
- *Project Management Success influences Product Success* – This means that project management success can influence the achievement of product success, but it is unlikely to prevent product failure.
- *Project Success is affected by time* – In cases of product success, judgment is made once the product is utilized and this is made years after the project's completion. For project management success, judgment if the project has successfully met the objectives of time, cost and quality is a short-term measure that is made during or at completion of the project [Baccarini, 1999]

According to Babu and Sudhakar success criteria according to owners, designers and contractors are as follows [Babu & Sudhakar, 2015]:

Owner's criteria

The owner's criteria for measuring the success are: on schedule; on budget; quality; function for intended use; aesthetically pleasing; end result as envisioned and return on investment.

Designer's criteria

Designer's criteria for measuring success is like this: quality architectural product; satisfied client; met project budget and schedule; met design fee and profit goal;

minimal construction problems; professional staff fulfillment; socially accepted; client pays and well defined scope of work.

Contractor's criteria

The contractor's criteria for measuring success is this: meet schedule, under budget; profit; safety; quality specification met or exceeded; client satisfaction and no claims by owners or subcontractors.

Common criteria

The common criteria that appears in all the lists (designer, owner and contractor) are these factors: time, budget and profit (costs). This means that the owner wants the project on time and on budget, and the designer and contractor expect some profit from the project.

Unique criteria

Each group has its own unique criteria. The designer looks for a project that increases the level of professional development and satisfaction among employees, while safety is a high-priority issue for the contractor because their employees are more at risk during the construction of the building [Babu and Sudhakar, 2015].

Atkinson divided the project success into three stages: the first stage being 'the delivery stage, the process: doing it right'; the second stage being 'the post-delivery stage, the system: getting it right', and the third stage being 'the post-delivery stage, the benefits: getting them right'. His paper suggests that the golden triangle of project management could be developed to become the square-route to understand success criteria: iron triangle, information system, benefits (organizational) and benefit (stakeholder community) [Atkinson, 1999]. In this way, it is provided a more realistic and balanced indication of project success.

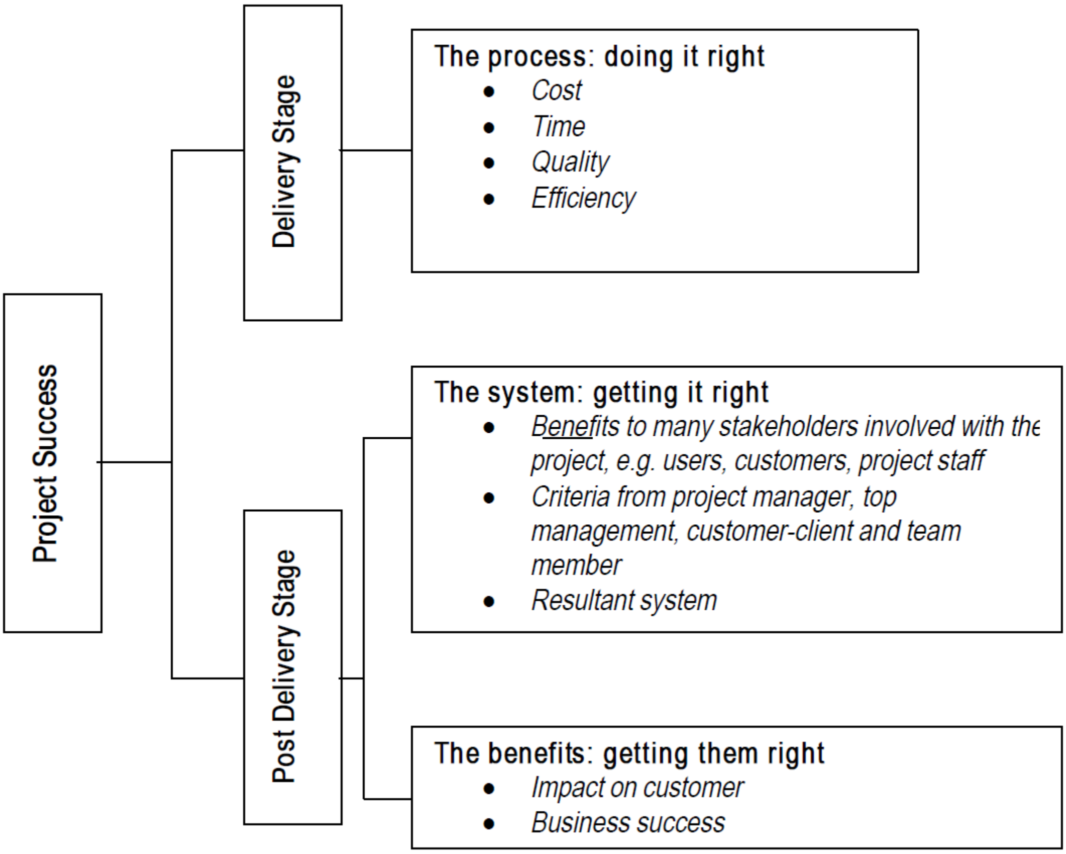

Figure 2. Atkinson's model of measuring project success [Atkinson, 1999]

2.3 Key success factors that affect the performance of the construction projects

2.3.1 Main difference between success criteria and success factors

According to Cooke-Davies there is a conceptual difference between success criteria and success factors. The success criteria belongs to specific measurement which needs to be formulated in order to conclude whether the project succeeds or fails. Success factors are more about particular levers that can be used by project manager to increase a probability of successful outcome of a project [Cooke-Davies, 2002].

In a difference with the project success criteria, that are the measures by which are judged the successful outcomes of a project and these are dependent variable that measures project success; the project success factors are all the elements of a project that can be influenced to increase the likelihood of success and these are independent variable that makes the success more likely. Success factors are those inputs to the management system that lead directly or indirectly to the success of the project or business. Both project success factors and success criteria are not universal for all projects. In the case of project success factors different projects and different people prioritize different sets of success factors, while in the case of project success criteria varies from project to project and what it is acceptable in one project without impact on perceived success is deemed an abject failure in another project [Babu & Sudhakar, 2015].

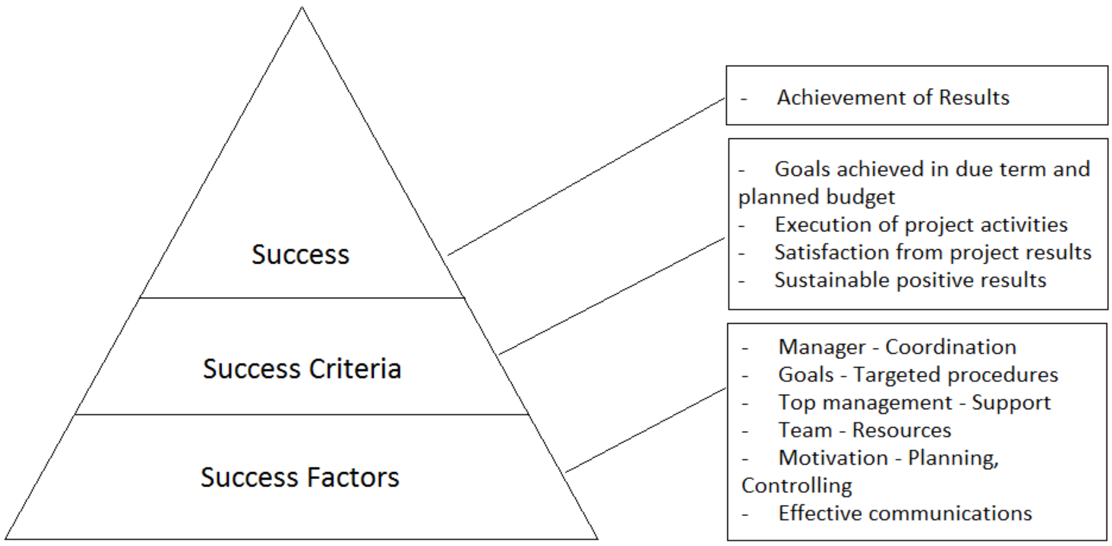

Figure 3. Conceptual model of critical success factors and project success [Babu & Sudhakar, 2015]

The conceptual model above reveals the basic constructs and relationships between critical success factors, success criteria and project success *(Fig 3).*

2.3.2 Critical success factors (CSF)

Critical success factors or CSFs are the characteristics, conditions, or variables that can have a significant impact on the success of the project when properly sustained, maintained or managed. There is a very close link between the type and scope of projects and respective critical success factors [Babu & Sudhakar, 2015].

Many studies are done to determine the critical success factors. Most of them are project specific and they concentrate on the performance measurement at the project level.

The most important success factors within the project life cycle are as follows:

1. Project Mission
2. Top Management Support
3. Competence of Project Manager
4. Project schedule/Plan
5. Client consultation
6. Competence of Project Team Members
7. Quality of Suppliers and Subcontractors
8. Technical tasks
9. Client Acceptance
10. Monitoring and feedback
11. Communication
12. Troubleshooting

The classification of critical success factors is done by Schultz, Slevin and Pinto. According to them, there are two groups of factors, strategic and tactical, which influence project performance at various stages of project life cycle. The strategic group consists of factors such as: project mission, top management support and project scheduling. The tactical group includes factors such as: human resource selection, client consulting and financial resources to achieve strategic plans [Schultz, Slevin & Pinto, 1987].

CSFs can be grouped under seven main categories that are: (1) Project Management factors; (2) Procurement-related factors; (3) Client-related factors; (4) Design team-related factors; (5) Contractor-related factors; (6) Project Manager-related factors; and (7) Business and Work Environment related factors.

- **Project Management Factors**

The variables in project management include adequate communication; feedback capabilities; control mechanisms; monitoring; coordination effectiveness; troubleshooting; decision making effectiveness; plan and schedule followed; project organization structure, and related previous management experience. There are a lot of attributes that will affect this factor, including control mechanism, planning effort, communication system, feedback capabilities, organization structure, control of subcontractors' works, safety and quality assurance and the overall managerial actions.

- **Procurement-related Factors**

There are two ways to measure this factor: procurement method and tendering method. Procurement method is the selection of the organization for the design and the construction of the project and the tendering method is the procedure adopted for the selection of the project team and main contractor.

- **Client-related Factors**

These are concerned with client characteristics, client type and experience, project financing, well-defined scope, knowledge of construction project organization, client confidence in the construction team, client project management and owner's risk aversion.

- **Design team-related Factors**

The factors consist of project design complexity, design team experience and mistakes/delays in producing design documents.

- **Contractor-related Factors**

The factors are: site management, supervision and involvement of subcontracting, contractor experience, effectiveness of cost control system, contractor's cash flow and speed of information flow.

- **Project Manager-related Factors**

The variables under this factor consist of the skills and characteristics of project managers, their experience, commitment, competence, and authority. Team spirit is also important, because a construction requires team spirit.

- **Business and Work Environment-related Factors**

Environment is described as all the external influences on the construction process. The attributes that are used to measure this factor are economic, social and political environment; physical environment; industrial relation environment, and level of technology advanced.

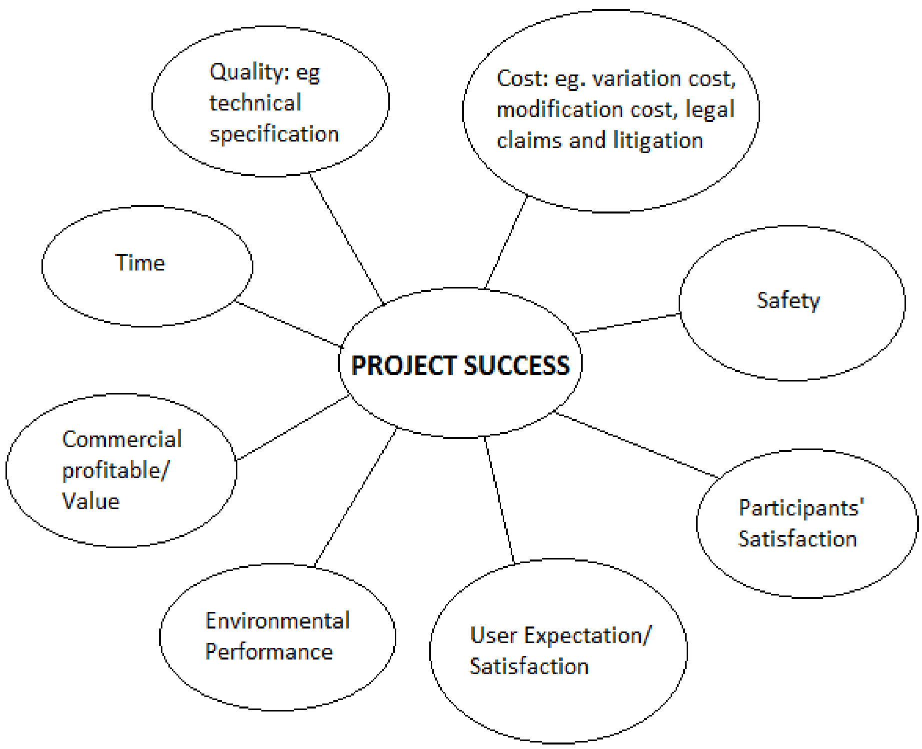

Figure 4. Project Success Factors

Figure 4 includes some main factors that influence the project performance such as: time, cost, quality, safety, value, environmental performance, participants' satisfaction and user expectation/satisfaction. There are a lot of other factors too *(Fig 4).*

2.4 Budget-Scope-Schedule triangle

2.4.1 Scope

'Time is money' – Benjamin Franklin

For the time criteria the focus is on project's plan and on a project's schedule. Project planning is the process of identifying all the activities necessary to successfully complete the project. Project scheduling is the process of determining the sequential order of the planned activities, assigning realistic durations to each activities, and determining the start and finish dates for each activity [Oberlender, 2000].

Table 2. Desired results of project planning and scheduling [Oberlender, 2000]

Desired Results of Project Planning and Scheduling
1. Finish the project on time
2. Continuous flow of work (no delays)
3. Reduced amount of rework (least amount of changes)
4. Minimize confusion and misunderstandings
5. Increased knowledge of status of project by everyone
6. Meaningful and timely reports to management
7. You run the project instead of the project running you
8. Knowledge of the scheduled times of key parts of the project
9. Knowledge of distribution of costs of the project

10. Accountability of people, defined responsibility
11. Clear understanding of who does what, when and how much
12. Integration of all work to ensure a quality project for the owner

The most common techniques for measuring time are:

- Performance Measurement
- Project Management Software (ex. Prima Vera)
- Schedule Comparison Bar Charts
- Critical Path Method (CPM)
- Program Evaluation and Review Technique (PERT)
- Network Analysis System (NAS)

2.4.2 Budget

For the budget or cost criteria the focus is on a project's budget. The budget for a process is the maximum amount of money the owner is willing to spend for design and construction to economically justify the project [Oberlender, 2000]. The budgeting process focuses on determining the cost of project activities and establishing a cost baseline. The cost baseline is a record of the planned cost for a project or project phase.

Cost management includes [Stojčetović, Lazarević, Prlinčević, Stajčić, & Miletić, 2000]:

- *Estimate costs*: approximation of the monetary resources needed to complete project activities
- *Determine budget*: aggregating the estimated costs to establish cost baseline
- *Control*: monitoring the status of the project and managing changes to the cost baseline

The most common techniques for measuring the cost criteria are:

- Earned Value Method (EVM)
- Forecasting
- Trend analysis [Stojčetović et. al., 2000].

2.4.3 Quality

There are a lot of terms and definitions that are used to describe quality.

Quality, according to one of the definitions in the British Standards 4778 is 'The totality of features and characteristics of a product (or service) that bear on its ability to satisfy a given need' [British Standard Publication, 1991].

In terms of project success, we can also use the term *'quality grade'*. Wideman defines the term quality grade as "a particular attribute of an item, product or service, which meets all the minimum requirements but which may be delivered according to a class ranging from utility (purely functional) to 'world class' (equal to the best of the best) [Wideman, 2000].

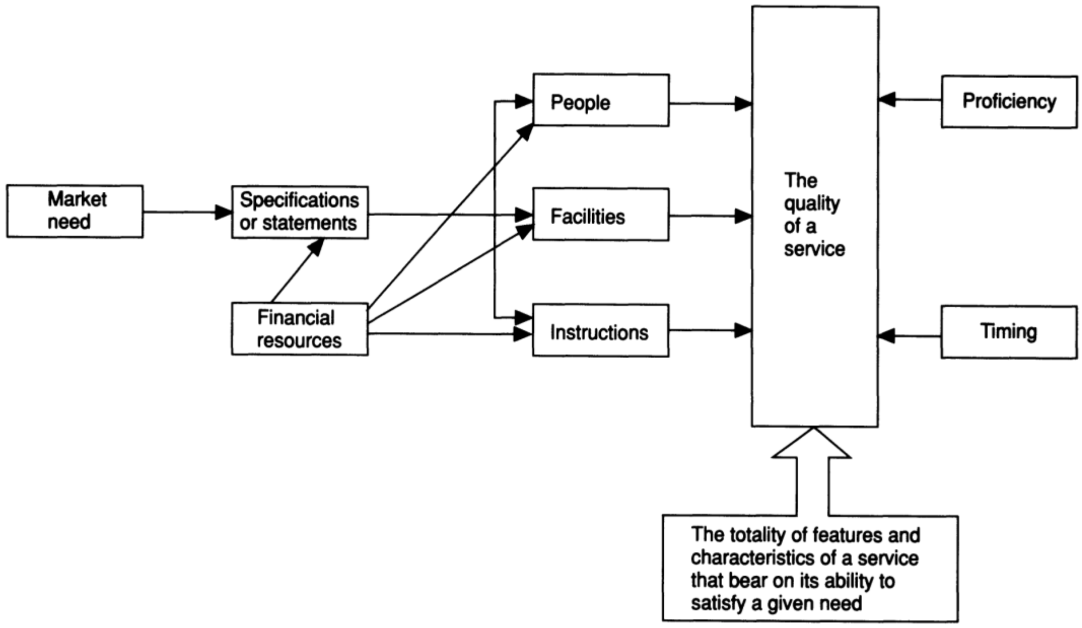

Figure 5. Quality determinants and measures [O'Neill, 1989]

Quality assurance is to ensure that a project has been so designed and constructed that it performs as expected in service. It is the result of a planned system which generates confidence that services will be performed satisfactorily. Quality assurance, therefore offers evidence of quality.

Quality control is the implementation of quality assurance actions which control the processes or measure the characteristics of services/products to the specified requirements [O'Neill, 1989].

The most common techniques for measuring the quality criteria are:

- Control charts
- Histograms
- Pareto charts
- Statistical sampling
- Cause and effect diagrams
- Scatter diagrams

2.4.4 Relationship between the iron triangle

As mentioned earlier there are three main parameters that define project management and define a project's management success: Scope, Budget, and Schedule. Over 50 years these parameters are used in project management to measure project success. These three parameters should be clearly defined when they are given to the project manager. Scope represents the work to be accomplished: the quantity and the quality of work. Budget refers to costs that can be measured in Albanian Lek ALL and/or labor-hours of work. Schedule refers to the logical sequence and timing of the work to be performed. Meanwhile, the quality is an integral part of scope, budget and schedule and it should meet the owner's satisfaction [Oberlender, 2000].

This triangle is known in project management as 'the iron triangle'. The triangle was named like this because although the sides can shorten or lengthen, they are unbreakable. They can ebb and flow as needed but they are in constant contact and must adjust as other sides do [Stojčetović et. al., 2000].

In every project the relationship between these parameters is interdependent. This means that the relationship of the parameters of the iron triangle is such that if any of the three changes, then at least one other parameter is likely to be affected. Increasing the quality will increase the amount of time needed, which will also lead to an increase in cost. Also, a tight time schedule could lead to a decrease in quality and subsequent increase in cost. The iron triangle is an excellent tool for the project manager to discover priorities and motivation for the various stakeholders and how well the project is understood [Stojčetović et. al., 2000].

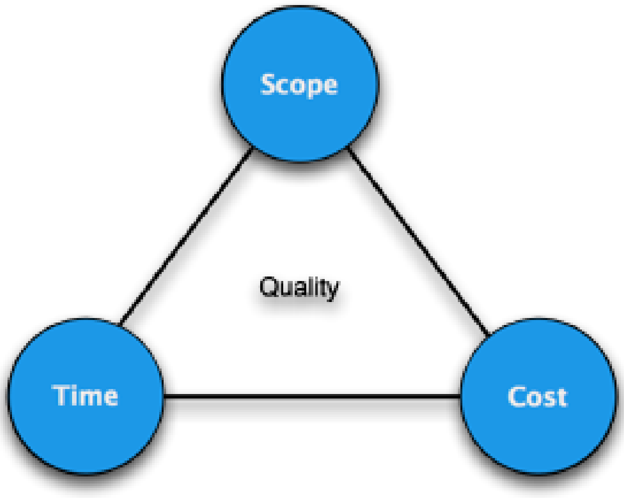

Figure 6. The 'iron triangle' of project management

But how does the relationship between time cost and quality function? Figure 7 illustrates a model that represents the relationship between cost quality and time *(Fig 7).*

This model is represented by Saputra and Ladamay. The process is started with a standard process that consists of baseline time and baseline cost. If the process has quality requirement, then a quality check mechanism is required. If the result meets the requirement, then it is gone to the next process. If the result fails, then the next question is what kind of corrective actions is needed or any consequences for this situation. The time is represented by the baseline time and additional time if the quality-cost process fails to meet the quality requirement. Cost is represented by cost function and additional cost if quality-cost process fails to meet the quality requirement. The quality is represented by a quality-cost mechanism with success and failure probability and a set of options for corrective actions/consequences for failure situation [Saputra & Ladamay, 2011].

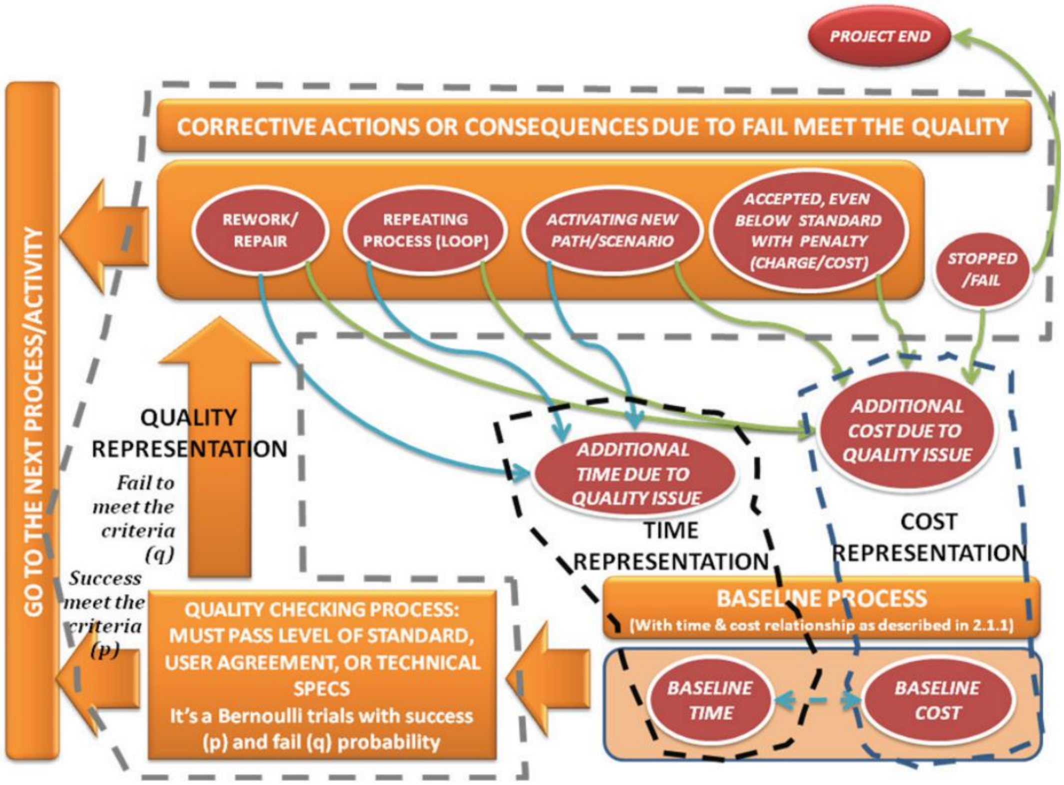

Figure 7. Quality-Cost-Time Relationship Model [Saputra & Ladamay, 2011]

2.5 The performance of engineering projects through the processes of monitoring and controlling

The process of monitoring and controlling of the quality of the construction works, schedule and costs, is the stage during which it is collected and analyzed the data that is obtained from the site and corrective actions are taken. As for the part of the audit, it is done after the end of the engineering project and is a process which makes the final technical and financial evaluation of the performance of the engineering project.

During the phases of project monitoring and control these processes are carried out:

1. Evaluation of the physical and financial advancement of the engineering project.

2. Calculation of the project performance indicators with Earned Value Method.

3. Analysis of the quality of construction processes.

4. Re-examination and analysis of the impact of risks.

5. Re-planning schedule and costs [American National Standard, 2008; Kemps, 2004].

2.5.1 Monitoring the Project

The monitoring process starts when most of the activities that are defined in the Work Breakdown Structure (WBS) have begun to be executed. Initially, during the monitoring process, data are gathered about the advancement, schedule, volumes and the costs of the project. Subsequently these data are processed by assessing their impact on the partial or total project, which allows the identification of deviations related to predefined standards during the planning phase. The methods that is used for monitoring is the ″Button Up Method″, by performing measurements for each finite activity and climbing into bigger activities that are defined in the work breakdown structure. The purpose of this phase is to keep within predetermined limits all performance indicators such as deadlines, costs, the quality of the materials, etc [Passenheim, 2008].

The effectiveness of the monitoring and control process depends on the frequency of the gathering of data, which is determined during the development of the project management plan. Frequency of data collection is influenced by the complexity and size of the project, but also the level of risk that is calculated during the planning stage. It is important the fact of finding an optimal frequency ratio of the control of the project, because frequencies would frequent high costs and obstacles in finishing the project. Also low frequency of the monitoring process decreases accountability of project implementation. Determining the frequency of the control process is a task of the Project Manager, who combines the data collected from the site with targets that were determined during the planning phase. Figure 8 indicates the Diagram of the Process of Monitoring and Control *(Fig 8)*.

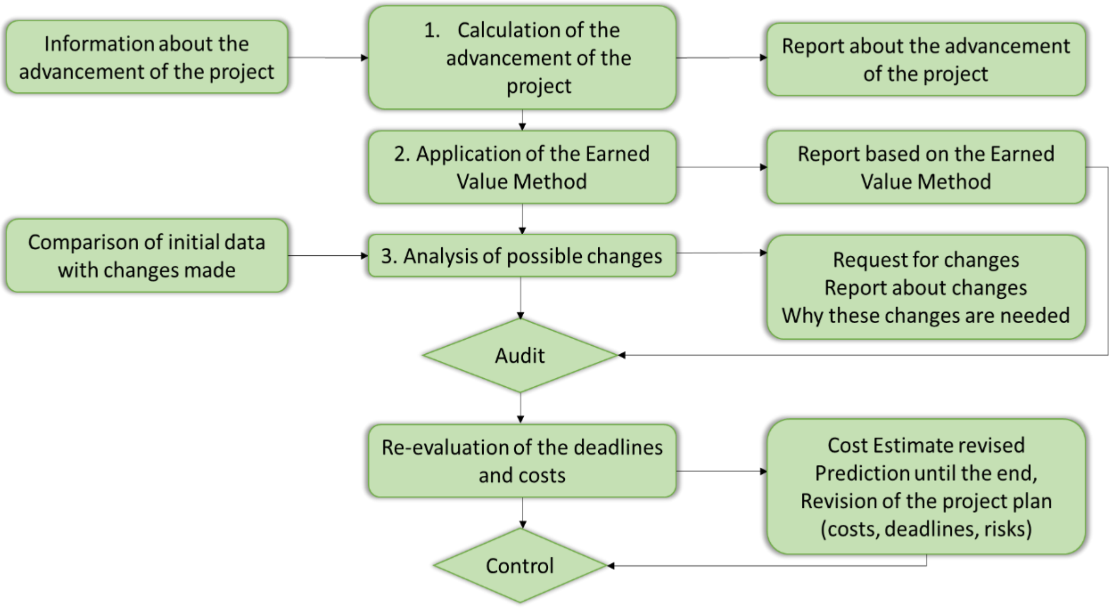

Figure 8. Diagram of the process of monitoring and controlling

2.5.2 Advancement of the project

Calculating the advancement of the project is the first phase of controlling an engineering work. The objective of this process is to determine which parts of the project are finished and which parts are in the process, relying on the process chart of the works that is determined at the initial stage, estimates, and signed installments and findings in the site.

2.5.3 Earned Value Method (EVM)

Traditional methods of assessing quality and performance of an engineering project, are usually focused on shared control of physical advancement, cost and schedule, making parallel overviews of the parameters, but not integrating them into a single technique. This gap is filled by the application of Earned Value Method [Gapaldo & Volpe, 2010].

For this reason, in 1967 was applied the EVM by US Department of Defense, which served to standardize the management and performance (cost, schedule, quality) of the contracts that have implanted various contractors. According to the definition of PMBOK 2008, the Earned Value Method is a method that is used to calculate the performance of a project by integrating schedule, costs and physical advancement of the project in a certain time (T_i) [American National Standard, 2008].

Using this method enables a detailed assessment of the project, identifying deviations from the initial planning. Accurate identification and immediate terms and costs deviations enables project managers to perform corrections.

EVM method goes a step ahead of traditional accounting methods, assessing the advancement and performance in a moment of time T (current), to predict the future performance. Feature of this method is to compare the activities that are completed in the time frame (T) assessment, with those that are predicted in the initial phase of the project. Practically it verifies the costs in a given moment of time T (timenow) by comparing the value of the physical part of the project that is completed with the value of the part that is estimated [PMI, 2005]. EVM is limited in use in the calculation of indirect costs.

CHAPTER 3

METHODOLOGY

The methodology used in this thesis is the qualitative method. This method was chosen because it can study complex phenomena within their contexts. This method provides insights into the problem and helps to develop ideas or hypotheses for potential quantitative research. For this reason, a case study was implemented, because it was thought to be the most suitable solution for the topic. A case study is an empirical enquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident [Yin, 2009]. The reason that this method was chosen is because case studies can answer questions like how and why. Case studies can have different purposes, such as: explanatory, exploratory or descriptive.

The method used in this thesis, is going to be described below, theoretically, but also practically. Theoretically, the methodology used in the paper can be divided into two main parts: Calculation of the Advancement of the Project and the Calculation of the Earned Value Method, which includes Calculation of Performance Indexes according to Costs and Schedule, Calculation of Forecasting Indexes, Calculation of Future Performance Indexes.

Practically, there are two engineering projects that were chosen to be the main case study for this thesis. They are both road infrastructure projects. One of the projects is completed, while the other one is still in the construction process. The completed project is chosen to be studied with the purpose to analyze its final performance, while the project that is in the construction process is chosen to analyze the performance of its completion according to the schedule and costs, but also to forecast the future prediction, in order to do be possible to do corrective actions to the project.

The main goals of these methods used are:

- Calculation of performance indexes of the project.
- Calculation of future performance indexes according to costs and schedule of an uncompleted project.
- Implementing forecasting indexes of an uncompleted project.
- Calculation of future performance indexes.

3.1 Calculation of the Advancement of the Project

To determine the advancement of the works of each activity based on the method of advancement with percentage, the following formula is used [Gapaldo & Volpe, 2010]:

$$A_n = C_n \times w_n$$

(1)

Where:

A_n – the advancement of each activity *n*

C_n – estimated cost for each activity *n*

w_n – percentage of advancement for each activity *n*

It should be noted that A_n is a loaded advancement taking in account the weight of each activity throughout the engineering project.

To determine the advancement of the whole project at a certain time T_i the following formula that expresses the sum of all activities is used:

$$A_{whole} = \sum_{n=1}^{N} A_n$$

(2)

Determination of the advancement of the project as a percentage of the project at a certain time helps in calculating real costs and not those that are situational. This also helps in the use of Earned Value Method which will be mentioned later.

Choosing the method of calculation of the advancement of an activity is done based on the typology of the activity and the following criteria:

Table 3. Criteria for evaluating the assessment of the project [Gapaldo & Volpe, 2010]

0-100 **ON - OFF**	**50-50**	**According to the % of the advancement of the works**	**According to Milestones**	**According to Outputs/Inputs**
Advancement of an activity is called complete when it is completely finished. Application: Implementation of technical projects, engineering calculations, commissioning.	Physical advancement is called 50% if the activity has started, and 100% if the activity is over. Application: When the project is short-term.	Physical advancement is calculated on the basis of the percentage of work that is completed. Application: When the project is complex and long-term.	Advancement is calculated based on the milestones that are achieved. Application: When the project is planned to be completed in some long-term periods.	Physical advancement is calculated doing the report of the units used over initial units. Application: It is used in applications such as paving, masonry, signs placement, devices.

3.2 Calculation of Earned Value Method

3.2.1 The calculation of performance indicators of costs and plan

EVM method consists initially in calculating the three parameters, which are represented analytically and graphically:

- **Earned Value (EV)** – else is called Budgeted Cost for work performed (BCWP) which expresses the value of work actually committed in a moment of time T by the relevant price estimate, which can be expressed by formula [Gapaldo & Volpe, 2010]:

$$EV_n = BAC_n \times w_n$$

(3)

Where

EV_n – Earned Value for each activity *n*

BAC_n – Budget at completion which is the total cost of the project for each activity *n*

w_n – percentage of advancement for each activity *n*

The earned value of the whole project until its completion is expressed with the sum of the Earned Value for the whole activities that are measured at a point in time T_i:

$$EV = \sum_{1}^{n} EV_n$$

(4)

- **Planned Value (PV)** – else is called Budgeted Cost for work scheduled (BCWS). This curve represents the values provided to be spent in certain moments of time T_i as per the schedule plan of an engineering project.
- **Actual Cost (AC)** – else is called Actual Cost of work performed (ACWP). This curve represents the values of effective costs of the project at certain moments of time T_i.

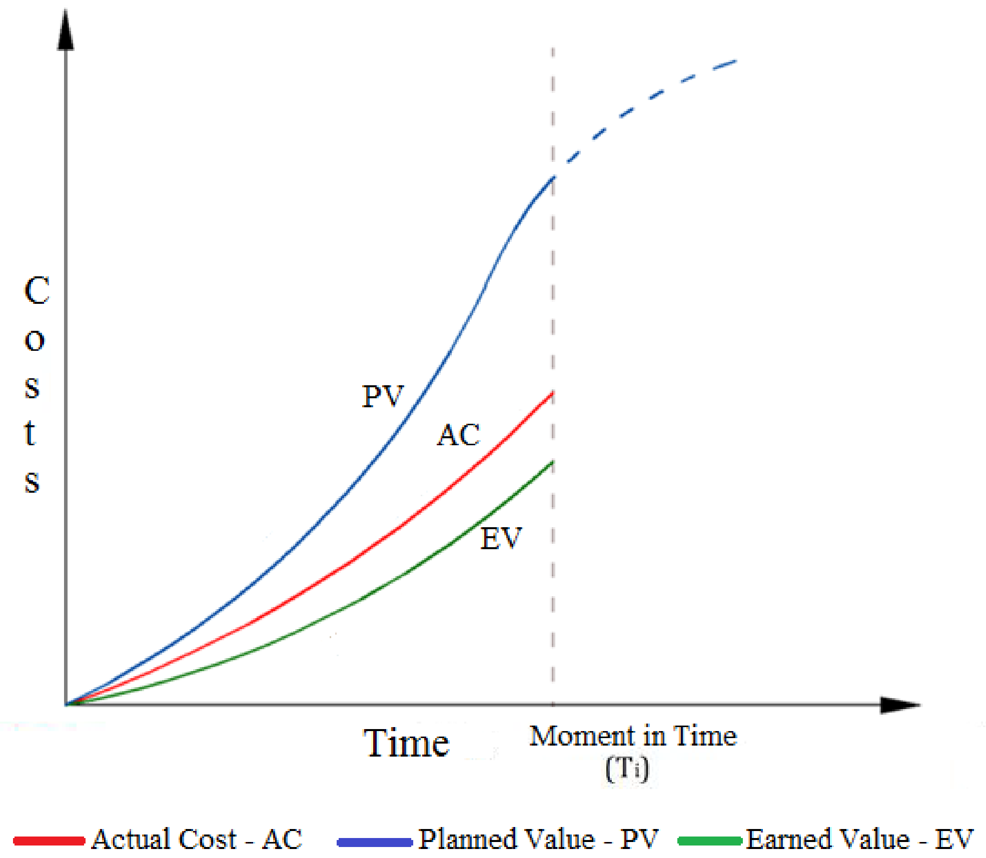

Figure 9. Graphical display of the parameters EV, PV, AC [Gapaldo & Volpe, 2010]

Determination of these parameters in a moment of time T by taking field data, documentation of the object or engineering evaluation makes possible the calculation of project performance indicators, which express the performance of the project in costs and schedule [Fleming & Koppelman, 2000]. These indicators are represented in Table 4 *(Tab 4)*.

Table 4. Indicators of the project performance [Fleming & Koppelman, 2000].

Cost Variance (CV)	**Schedule Variance (SV)**	**Cost Performance Index (CPI)**	**Schedule Performance Index (SPI)**
Earned Value – Actual Cost Formula: CV = EV – AC Difference between the estimate value for the completed works with the value that was actually spent when these works were carried out.	Earned Value – Planned Value Formula: SV = EV – PV Difference between the estimate value for the completed works with the value that was supposed to be spent according to the plan.	Earned Value / Actual Cost Formula: CPI = EV / AC Project performance in terms of costs. CPI>1 indicates that the completed works are with lower costs than forecasted. CPI<1 indicates that the completed works are with higher costs than forecasted, this means that costs are exceeded. Indicator of efficiency.	Earned Value / Planned Value Formula: SPI = EV / PV Project performance in terms of schedule and quantities/volumes. Demonstrates how the project is ahead or behind in schedule. SPI>1 indicates that are performed more quantities/volumes than forecasted. SPI<1 indicated that there are performed les works than expected. Indicator of effectiveness.

Figure 10 shows graphically the relationship between the Earned Value, Planned Value and Actual Cost in a given moment of time *T (Fig 10)* [Gapaldo & Volpe, 2010].

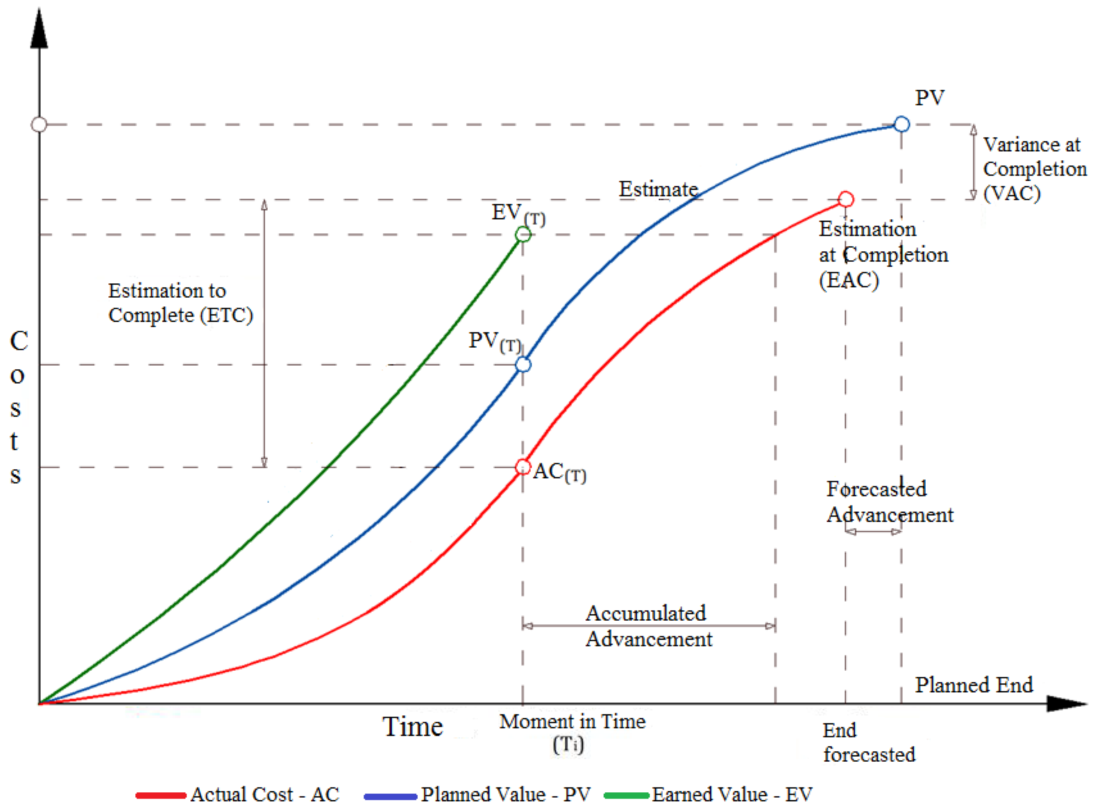

Figure 10. Graph of the relationship between EV, AC and PV. (Benefits in costs and shortening of schedule) [Gapaldo & Volpe, 2010]

The calculation of performance indicators helps project managers to have a clear view of the construction processes that are being implemented. When all the indicators that were mentioned above, measured at a moment in time T, as Cost Variance CV > 0, Schedule Variance SV > 0, Cost Performance Index CPI > 1, Schedule Performance Index SPI > 1, then the implementation of the project is within all the parameters that were forecasted. This means that in the project implementation there are savings in the budget and also the schedule was shortened. The figure above shows the graph of the relationship between EV, AC and PV, where the performance indicators are all greater than 1. This is the most favorable case, where the project implementation performance of the engineering project is maximal. Below it is shown the table of the performance of the engineering project based on different combinations of indicators of costs and schedule *(Tab 5).*

Table 5. Project performance in different combinations [Sagar & Gayatri, 2012]

Performance Indicators		**Costs**		
		CV < 0; CPI < 1	**CV = 0; CPI = 1**	**CV > 0; CPI > 1**
Schedule	**SV < 0; SPI < 1**	Over budget / Behind schedule	Behind schedule = Delay	Under budget / Behind schedule
	SV = 0; SPI = 1	Over budget	In Schedule	Under budget
	SV > 0; SPI > 1	Over budget / Ahead schedule	In Advance	Optimal Under budget / Ahead schedule

Otherwise, when one of the above indicators is less than 1, then at least one of the activities of the project is not going according to expectations in terms of cost, volume or schedule [Sagar & Gayatri, 2012].

As shown below in Figure 11, the relationship between the EV, PV, and AC of an engineering project where the Cost Variance CV < 0, Schedule Variance SV < 0, Cost Performance Index CPI < 1 and Schedule Performance Index SPI < 1 *(Fig 11)*. In this case the project is being developed with low performance, where the estimated cost is exceeded compared with volumes committed, and also the schedule of the completion of the project is delayed. When the Cost Performance Index CPI < 1 and the Schedule Performance Index SPI ≥ 1, the project has exceeded the schedule, and has completed less volumes than forecasted. In the case when the Cost Performance Index CPI ≥ 1 and the Schedule Performance Index SPI < 1, although the project has exceeded the time and has completed less volumes than forecasted, the project has had savings in budget for the volumes that were performed.

Project performance in the chart below is calculated at a given point time T, and the performance indicators were found, where all the results were unfavorable.

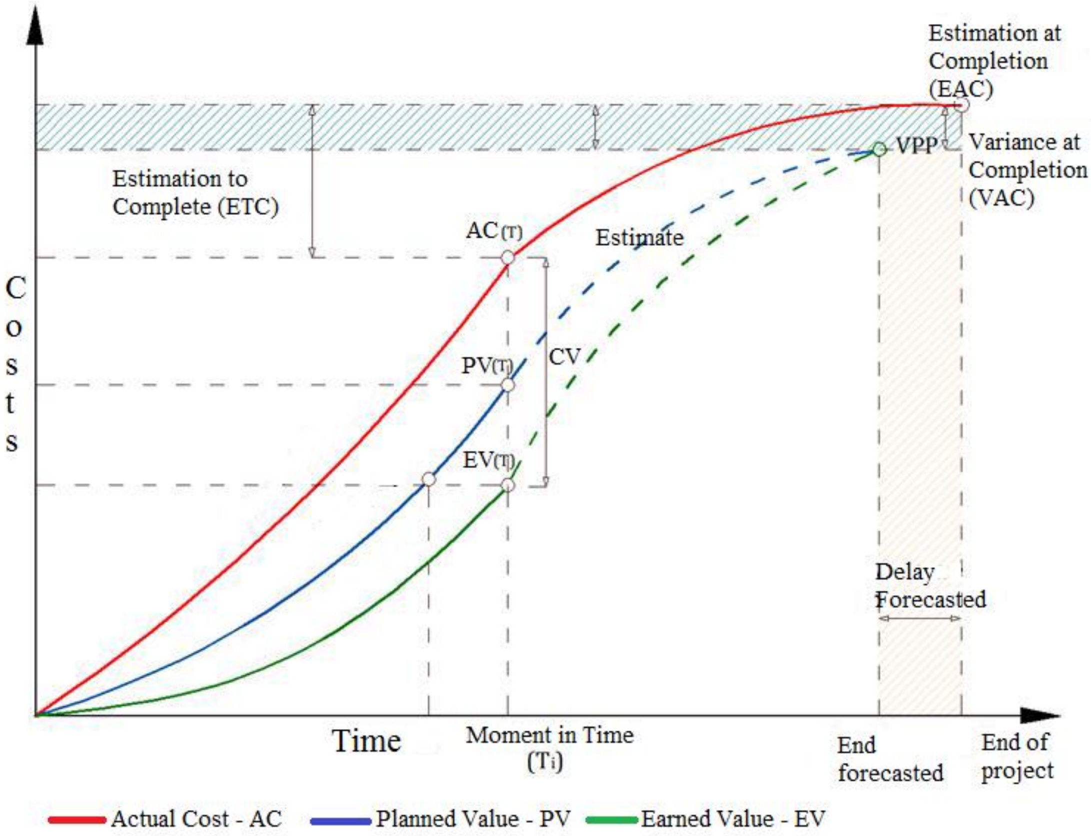

Figure 11. Graph of the relationship between EV, PV, AC (Exceeding the schedule and costs) [Gapaldo & Volpe, 2010]

Analyzing the values of the above indicators makes possible the completion of correctional actions and also forecasting for continuing processes.

3.2.2 Calculation of Forecasting Indexes

Forecasting of schedule and costs is done by calculating the forecasted values, which are expressed as below [Gapaldo & Volpe, 2010]:

1. Estimation to Complete (ETC) – expresses the forecast for the expected cost required to complete all the remaining works. This evaluation is done by taking into consideration Budget at Completion (BAC), Earned Value (EV) and the indicators of the performance of costs and plan. ETC is expressed by this formula:

$$ETC = EAC - AC$$

$$= \left(\frac{BAC}{CPI}\right) - \left(\frac{EV}{CPI}\right)$$

$$= \frac{BAC - EV}{CPI}$$

(5)

2. Estimation at Completion (EAC) – expresses the expected total cost required to finish all the works of the engineering project. This evaluation is done by summing the Actual Cost (AC) at a given moment in time T, with Estimation to Complete ETC. It is expressed by this formula:

$$EAC = \frac{BAC}{CPI}$$

$$= AC + ETC$$

$$= AC + \left(\frac{(BAC - EV)}{CPI}\right) \text{ (typical case)}$$

$= AC + (BAC - EV)$ (atypical case)*

(6)

Here, it is assumed that similar variances will not occur in the future.

3. Variance at Completion (VAC) – Expresses the variance of the total cost of the work and the expected cost. It is expressed by the following formula:

$$VAC = AC + ETC - BAC$$

$$= BAC - EAC$$

(7)

4. Final change of Schedule $\boldsymbol{CS_f}$ – expresses the time won or lost of the engineering project. It is expressed by the following formula:

$$CS_f = T + \frac{T_{final} - T_{estimate}}{SPI}$$

(8)

ETC, *EAC*, and *VAC*, CS_f are forecasting indicators, which make a quantitative evaluation of the final costs and schedule of the project, based on the performance indicators that are calculated at a moment in time T_i.

Quantitative evaluation of the *Earned Value* in a moment of time T_i requires a recalculation of the costs and time of the engineering project. Calculation of the *Earned Value* can be completed in analytical ways (the real physical evaluation of the project is done, its value in estimation, and the value that was actually completed).

3.2.3 Calculation of Future Performance Index

Except the forecast for the value that the project needs to be completed, also it is calculated the Future Cost Performance Index – CPI_{future} [Gapaldo & Volpe, 2010]. Differently from *CPI*, this index does not calculate the performance of the project measured until the moment of time *T*, but calculates the performance based on cost that the staff that completes the project needs to complete the processes and works according to the costs that were forecasted in estimation. This performance index is expressed by the report of Estimation to Complete and the Remaining Funds:

$$CPI_{future} = \frac{Estimation\ to\ Complete}{Remaining\ Funds} = \frac{(BAC - EV)/_{CPI * SPI}}{BAC - AC}$$

(9)

Another Index that can be calculated is the Future Schedule Performance Index – SPI_{future}, which calculated the performance in accordance with the schedule and volumes that the staff that implements the project should complete in order to complete the processes and the works in accordance with the volumes and the deadlines forecasted. It can expressed as below:

$$SPI_{future} = \frac{Estimate\ to\ Complete}{Remaining\ Work} = \frac{BAC - EV/_{CPI * SPI}}{BAC - PV}$$

(10)

3.3 Data and Specifications of the Projects

3.3.1 Project Road Kiri Bridge – Mjedë

For this case study there were taken two road projects that are constructed or are still in the process of construction in the area of Shkodër, Albania. The first one lays between the area of Shkodër and Mjedë in Shkodër. The project is named Reconstruction of road from Kiri Bridge to Mjedë. It is a completed project and the reason why this project is selected to be studied is to analyze the final performance of it.

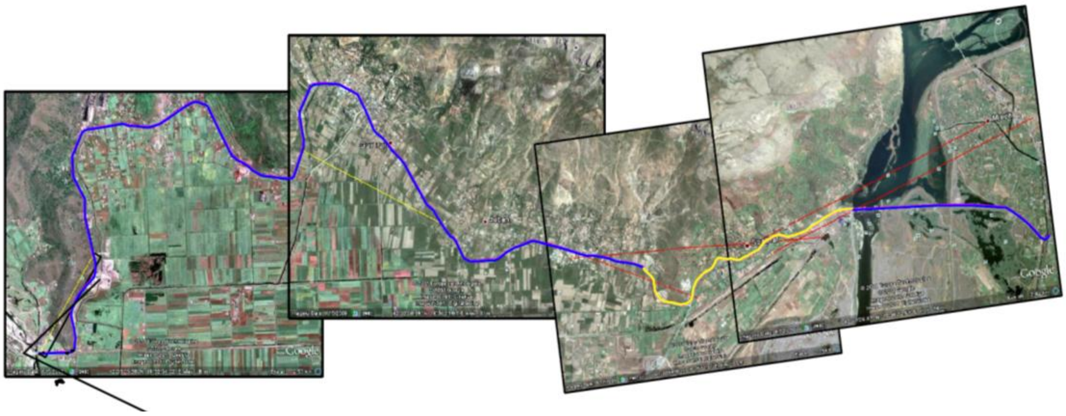

Figure 12. Project of the Road Kiri Bridge – Mjedë

It is important to chose a completed project because it is needed to know if the goals of the project that are set in the planning phase are achieved and also the funds are spent with accordance to how it is declared. The results that are taken from this analysis serve to create a database to correct the performance of the future projects.

The data for these two projects are taken from the construction company that was responsible for completion of these projects, "AlbTiefbau shpk" that is a construction company that is located in Shkodër. The total value of the project of Kiri Bridge until Mjedë is 61,897,905 Lekë. The project of this road consists of excavation, stone walls, concrete works, concrete ditches, scarification of the road, different layers of the road (gravel, crushed stones, binder course, wearing course), guardrails, road markings, and traffic signs. There were some changes that were done to the initial project, because the calculations for the technical project were done before and the road was demolished more until the time that the works started. The binder course and the wearing course was demolished more and this caused the project to change because the quantities that were predicted in the initial project for the binder course and the wearing coarse were not enough. This is why the funds that were initially predicted as reserve funds that were up to 5% of the total value of the project were used as an addition of the binder course with thickness t=4 cm.

The project started in 13.03.2016 and was predicted to end in 23.04.2016 with a duration of 6 weeks or 42 calendaric days. Instead there were delays due to atmospheric conditions, and the project was delayed with 7 calendaric days and it was finished in 30.04.2016. The project was completed in 49 calendaric days in total.

Figure 13. The Road Body of “Kiri Bridge – Mjedë” Project

The road has a thickness of B=6 m, and it consists of two lanes, being it 3 m each lane. The total length of the road is 13.7 km. Binder course has a thickness of t=4 cm, and the wearing course has also a thickness of t=4 cm. The gravel layer has a thickness of t=10 cm.

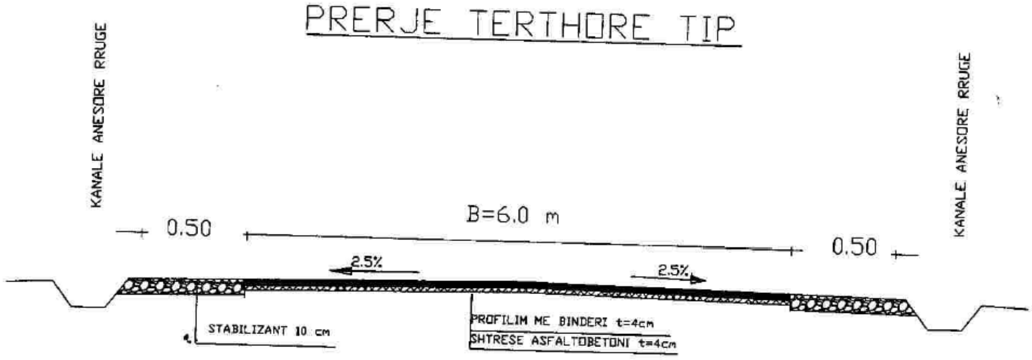

Figure 14. Typical Cross Section of the Road

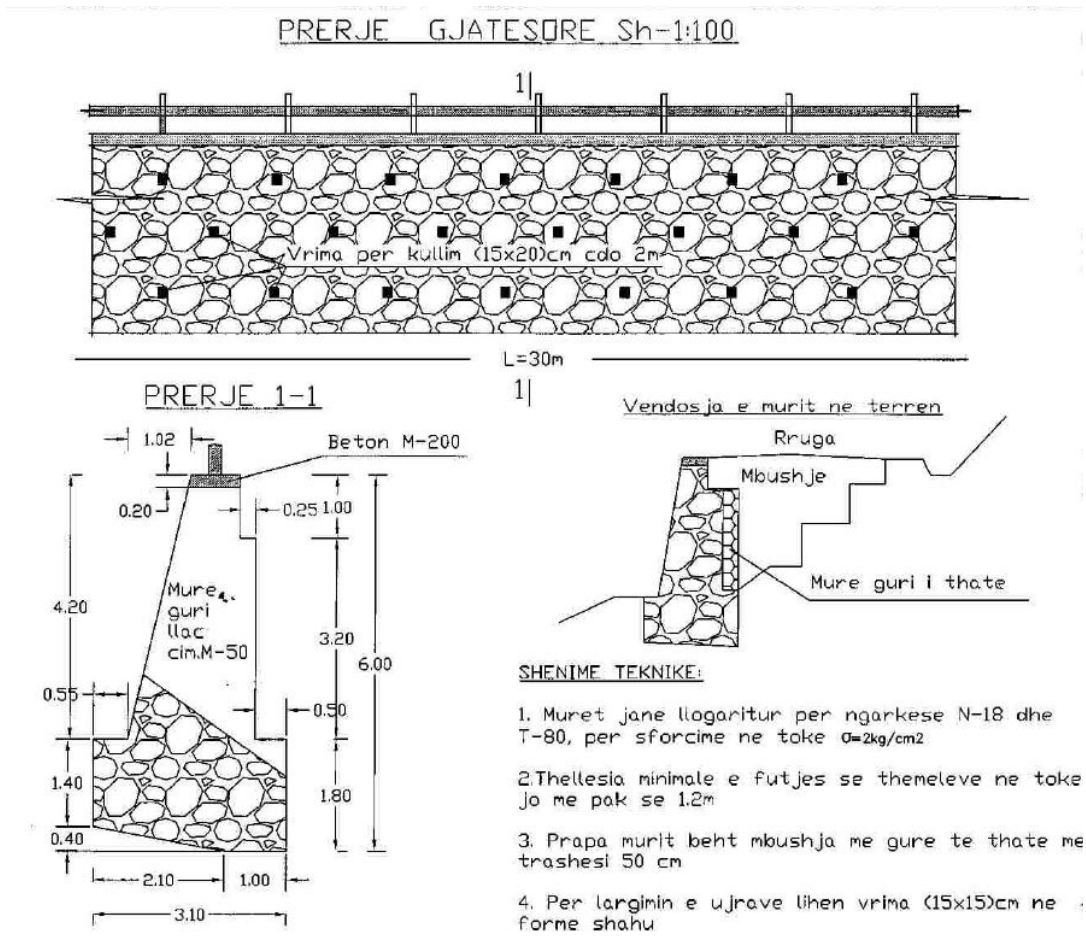

Figure 15. Longitudinal Cross Section

3.3.2 Project Road from Overpass of the Train – Mes

The second project that is chosen is from the Overpassing of the Train until Mes, near Shkodër area too. This project is also implemented by the construction company "AlbTiefbau sh.p.k". This project is still in the process of construction. The reason that this project is chosen is to analyze its performance of the completion of the project at a certain deadline and also to predict the future performance in order for future corrections to be done. The calculations of the performance indexes for an engineering project in the construction phase is done to give an analysis of the performance of its completion, in a certain moment of time (T). The results that are taken according to the performance of the project in a moment of time (T) serve to predict the future performance of the engineering project, in order to be within the parameters that are predicted in the planning phase.

Figure 16. Project of the road Overpassing of the Train – Mes

The total value of the project that is planned during the initial phase for the project of the Overpassing of the Train until Mess is 297,334,896 Lekë. And after changes of the project the value that was reached is 356,801,875 Lekë. The total length of the road is 3.79 km.

This project is planned to be in two main parts, the first being from Overpassing of the train until the Offspring Grude e Re, and the second being from the offspring Grude e Re until Mes. The first part of the project is from km 0+00 to km 0+600 and the second part is from km 0+600 to km 3+879. The project for the first part of the road predicts these works: Main road has 2 lanes with a width B=4 m each; Concrete ditches in both sides, with a width B=0.5 m each; Sidewalks in both sides with a width of B=2 m each, accompanied with road lighting; Greenery in both sides with decorative trees. The project for the second part is mostly the same, except that it changes the width of the lanes, it becomes from 4 m to B=3.5 m each.

Figure 17. Completed part of the project

The works that are estimated are like this: The project as planned, was divided into five main chapters: Reconstruction works, Road Lighting works, Displacement of electric wires (Low and Medium voltage), Construction of Electric Cabins, Cable Network, and Works that are covered by Reserve Fund (5%).

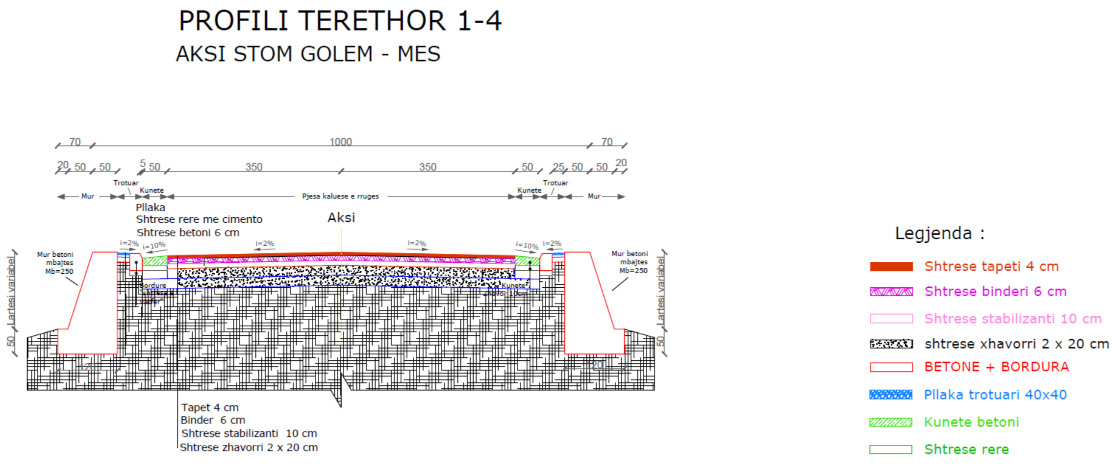

Figure 18. Typical cross section of the Road

Mesi road consists of different layers of the road, such as: wearing course with a thickness of T=4 cm; binder course with a thickness of T=6 cm; crushed stones with a thickness of T=10cm and granulometry G=0.0-0.20 mm; crushed stones with a thickness of T=20cm and granulometry G=0.0-0.31.5 mm; gravel with a thickness of T=20 cm.

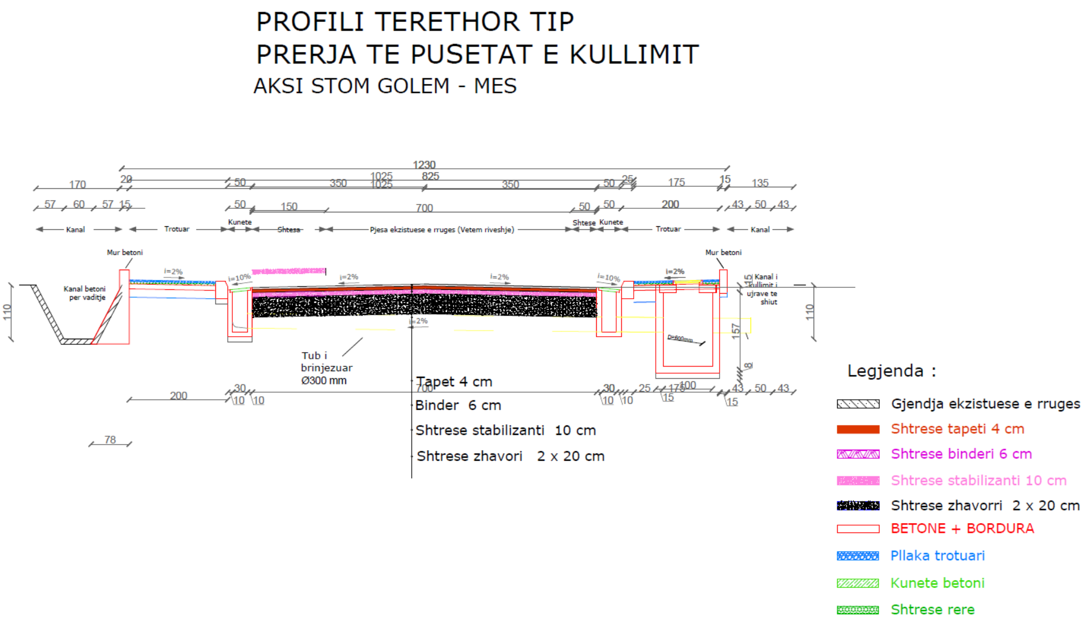

Figure 19. Typical Cross Section of the Road including Concrete Pits

The area of the overpassing of the train is a problematic area, due to the traffic and because it is an important joint point. The project at this part predicts a 2 lane road with width B=3.5 m each, pavements with a width of B=1 m each and one-lane offsprings for connecting with the main axis of Golem. This part was also predicted to strengthen the elevated part with concrete retaining walls, as well as strengthening of the offspring in the right side with concrete retaining walls.

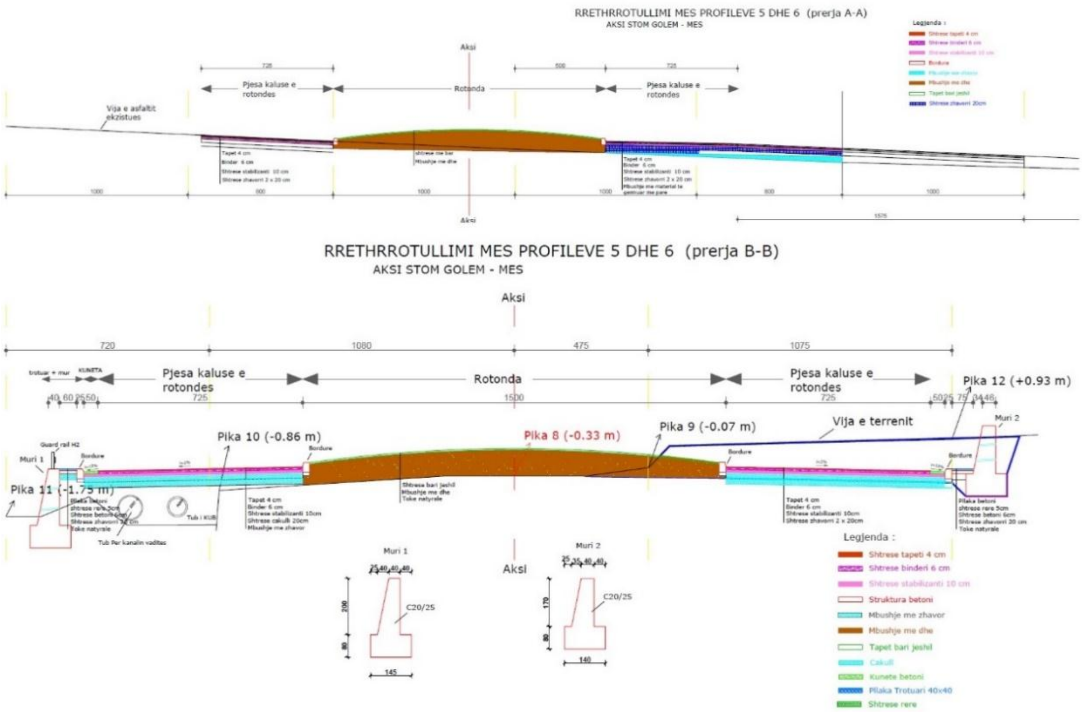

Figure 20. Cross sections A-A and B-B of a roundabout of the road

There are no new artworks constructed because that was not necessary. The existing bridges (the overpassing of the train with a span of S=47 m and the bridge over Shtroder with a span of S=6.0 m) are in good technical conditions and there was not predicted any construction intervention. The bridges will be completed just with metal parapets and with guardrails for the division of the sidewalks from the road. The changes of the project have required to change the size of the concrete retaining walls in the sides of the roads, because there were needed more excavation and filling.

Figure 21. During work at the Overpass of the Train

The beginning of the road is the overpassing of the train, which has two important offsprings, the offspring of Bardhaj in the right side and the offspring of Golem in the left side. The offspring of Bardhaj is predicted to be constructed as a two lane road with passage in both ways. This is due to the heavy traffic. The offspring of Bardhaj is controlled by vertical and horizontal traffic signs.

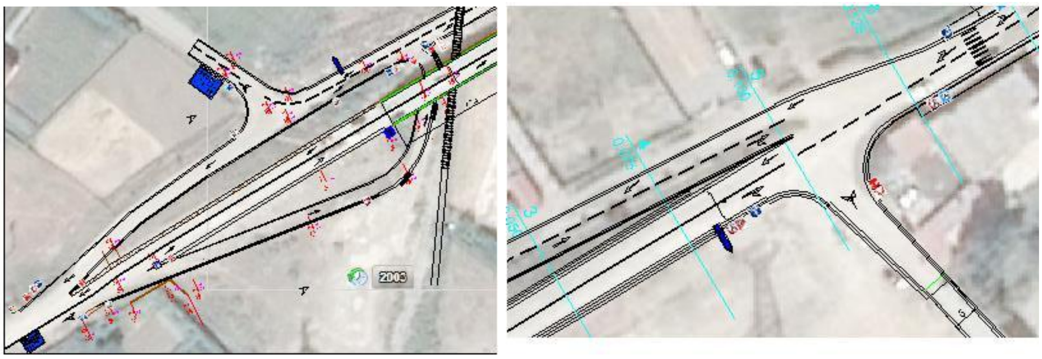

Figure 22. The offspring of Golem and the offspring of Bardhej

In 0.600 km is the offspring of Grude e Re which is predicted to be constructed in the form of a roundabout. This is because of the traffic, and because of the buildings that are around the roundabout is necessary and horizontal traffic signs are used.

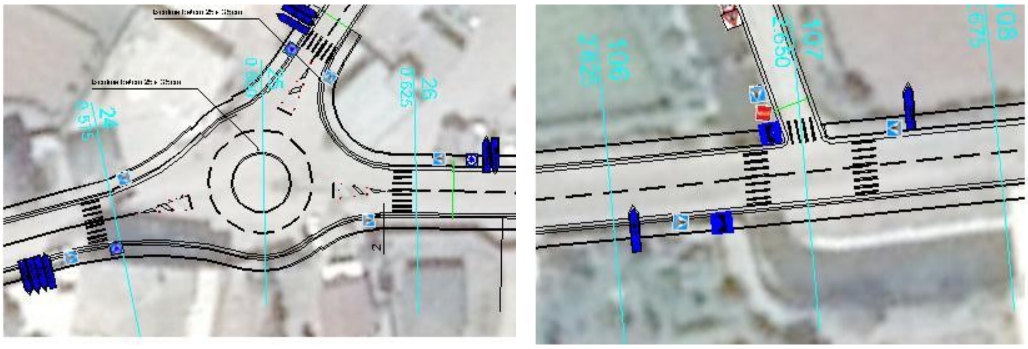

Figure 23. The roundabout of Grude e Re and the offspring of Pularia

In 2+650 km it is the offspring of Pularia. This area has not a lot of traffic so the offspring is simple. The traffic signs will be horizontal and vertical. The bridge has a san of 6.0 lm, and a total width W=8.0m. To construct the sidewalks, the bridge is going to be expanded by 2.0 m in both sides.

The road lighting is changed by changing the length between the columns of the lightning from 50 m to 30 m, and also the arrangement of the lighting in the connecting roads at the overpass is done. There were added from 168 columns in the initial project, to 268 columns to the final project.

During the initial project it was estimated that there was no need to do any expropriations, but the need to construct the connecting roads since the start of the object, the overpass of the train, the need to construct a parking lane and also the construction of roundabouts, it was estimated that it was necessary to build outside the area of the body of the road. This had brought the need to use the territory outside the body of the road that sometimes was in the ownership of private individuals.

The greenery is predicted to be done with decorative trees in both sides of the road. Mostly there were used Mediterranean plants with a height of 3-5m and in a distance of 5 m from each other. The sidewalks are constructed with a layer of concrete and with concrete tiles with dimensions 200x100x60 mm.

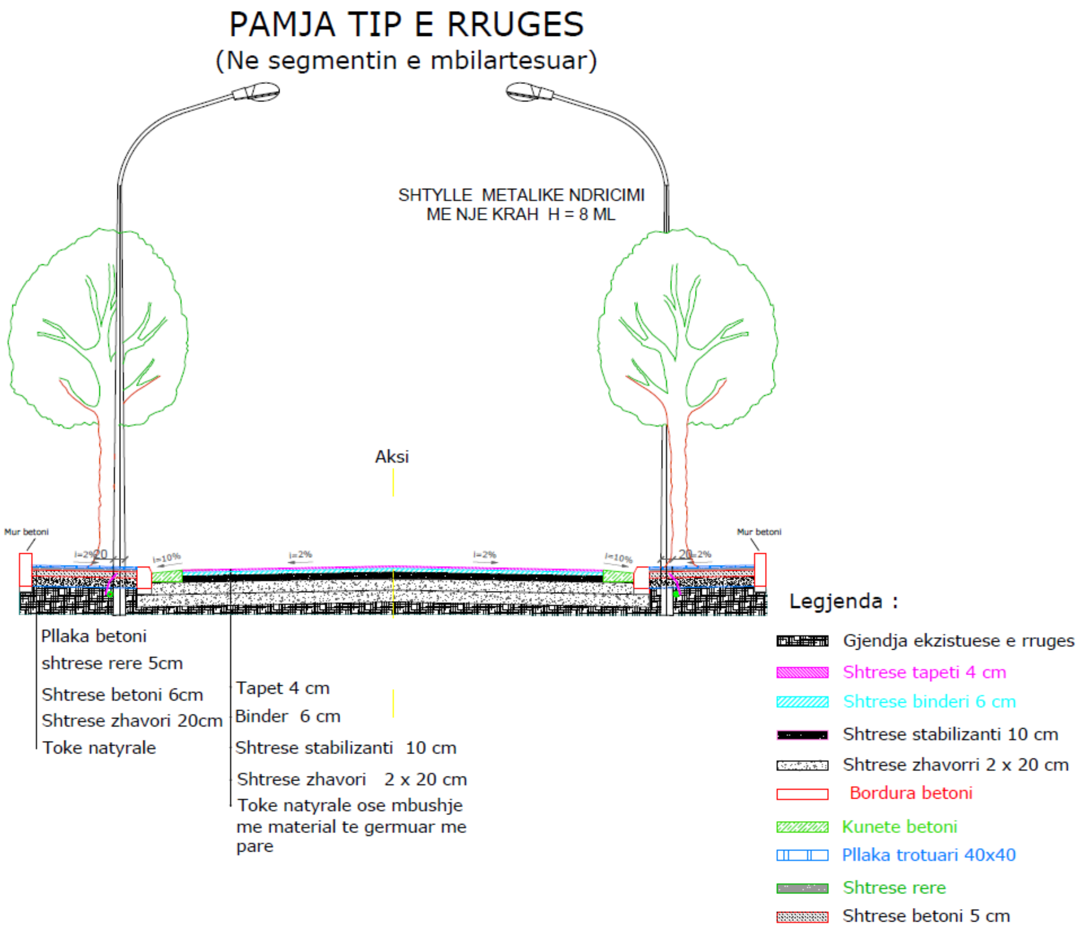

Figure 24. Typical view of the road

The project was planned to start at 01.04.2015 and was estimated to finish at 30.11.2015. The project was estimated to be completed in 8 months or in 245 calendaric days. There were made continuous changes of the deadline because of various reasons.

Some of these changes are:

1. The results of laboratory tests carried out in layers of existing road in the length of the road segment and surveys made in the body of the road in connection with the geological composition of the terrain where the road body passes.

2. Changing of the state of the existing road from the time of design until the commencement of the works from the Contractor.

3. The findings made in the object as a result of topographic measurements of the terrain and the line of the terrain that in the project is accept also as a benchmark project.

4. The need to change the layers of the road for achieving standards required as a result of changing grade lines and geological problems that represents the terrain where the body road passes.

5. Determination of technical details of the works of art, the walls and the contours of the road, in particular with regard to irrigation and drainage canals that accompany this road axis in its entire length.

6. Technical solutions in regard with the network's displacements and also the water supply pits.

7. Implementation of a modern street lighting standards with elements that save electricity.

8. Demolitions within the construction site.

All these reasons made that the project changed its final deadline to 15.05.2015. The project was 5 and a half months due its deadline, or else it is 167 calendaric days later than it was initially predicted.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Calculation of Performance Indexes of a completed engineering project

The project of the road from Kiri Bridge until Mjedë is the first project that is going to be taken into consideration, as it is a completed project, and the Performance Indexes need to be known in order to analyze the performance of this project according to costs and plan. For this project it was implemented the EVM method.
Because the project was totally completed there was no need to calculate the advancement of the project. The method ON-OFF is used in this case and the advancement of the works is 100% because the works are completely finished.
In order to calculate the Performance Indexes according to costs and plan, it was needed to calculate EV, CV, SV, CPI, and SPI. These were calculated by the formulas that are given in the methodology part.
For this project there were 17 items that were analyzed and the results are given and analyzed below.

1. *Cutting of small plants up to 10 cm*. The first item had the forecasted performance according to costs, where the Cost Performance Index calculated is $CPI = 1$, a value that indicates that costs of the work completed matches with the value of the volumes paid. According to calculations Schedule Performance Index is $SPI = 1$, this also means that the volumes forecasted in the planning stage are completed. These results show for the first item that was completed in budget and in schedule.
2. *Concrete ditches M-200*. This item has these results: Cost Performance Index is $CPI = 1.053 > 1$ and Schedule Performance Index is $SPI = 1.053 > 1$. This

means that there are completed more works than were predicted in the planning stage. Costs of these works are 5.3% more then the value of completed volumes, and were also completed 5.3% more volumes that were initially forecasted. These results show that the performance is optimal, so it is completed under budget and ahead schedule.

3. *Concrete coat M-200*. Cost Performance Index *CPI* = 1 and also Schedule Performance Index is *SPI* = 1. This item was also completed in budget and in schedule, and also the costs of the work completed matches the costs that was actually paid and also that the volumes that were forecasted in the planning stage are completed.
4. *Stone walls mortar cement M-50*. Cost Performance Index for this item is *CPI* = 0.358 < 1. This value shows that the costs of these works is 64.2% higher then the value of the completed volumes. Schedule Performance Index *SPI* = 1, this means that the volumes that were forecasted in the planning stage are completed, so the works were over budget, but ahead schedule.
5. *Dry stone walls*. Cost Performance Index is *CPI* = 1, and Schedule Performance Index *SPI* = 1. This item was completed according to forecasted schedule and costs.
6. *Gravel layer under the ditches*. Cost Performance Index is calculated to be *CPI* = 0.602 < 1 and Schedule Performance Index is calculated *SPI* = 0.602 <1. This value indicates that the costs of these works is 39.8% higher then the value of completed volumes and also that there are completed 39.8% less volumes that were initially forecasted. This item was over budget and also behind schedule.
7. *Scarification of the road*. Cost Performance Index *CPI* = 1, and also Schedule Performance Index *SPI* = 1, so this item was completed accordingly to schedule and to costs.
8. *Crushed stoned layer*. Cost Performance Index *CPI* = 1, and also Schedule Performance Index *SPI* = 1, so this item was also completed accordingly to schedule and to costs.
9. *Crushed stoned layer + embankment*. Cost Performance Index for this item is *CPI* = 2.571 > 1. This means that this item is completed over budget that was

initially predicted, in this case the costs of these works were 74.29% less than the value of completed volumes. Schedule Performance Index is *SPI* = 1, which means that volumes for these works are completed in the same amount that was predicted in the initial project.

10. *Binder course t=4 cm*. Cost Performance Index for this item is *CPI* = 1.965 > 1. This value shows that the item is completed over budget that was initially predicted, and the costs of these works were way less than the value of completed volumes. Instead, Schedule Performance Index is *SPI* = 0.745 which means that there were completed 25.5% less volumes than were initially predicted, and also that the item is behind schedule.
11. *Wearing course t=4 cm*. Cost Performance Index for this item is *CPI* = 1.188 > 1. This value shows that the costs of these works were 18.8% over predicted budget, and that are completed more works than are paid.
12. *Supply and placement of guardrails*. Cost Performance Index for this item is *CPI* = 0.123 < 1. This means that the performance according to costs is very low and that the costs of these works are 87.7% higher than the value of completed volumes. Schedule Performance Index is *SPI* = 0.447 < 1. This value shows that there were completed 55.3% less volumes that were initially predicted. This item is one of the lowest performances according to costs and plan in this project, as it is over budget and behind schedule.
13. *Supply and placement of guardrails for bridges*. Also this item had a very low performance. Cost Performance Index is *CPI* = 0.071 < 1. This means that the costs of these works are 92.9% higher than the value of completed volumes. Schedule Performance Index is *SPI* = 0.583 < 1, which means that there were completed 41.7% less volumes then initially predicted. This item is also over budget and behind schedule.
14. *Road markings*. Cost Performance Index is *CPI* = 1, and also Schedule Performance Index is *SPI* = 1, so this item was also completed accordingly to schedule and to costs.
15. *Excavation of foundation*. This item has also one the lowest performances in all the project. Cost Performance Index is *CPI* = 0.365 < 1 and Schedule Performance Index is *SPI* = 0.365 < 1. This value indicates that the costs of

these works is 63.5% higher then the value of completed volumes and also that there are completed 63.5% less volumes that were initially forecasted.

16. *Supply and placement of different vertical signs*. Cost Performance Index is *CPI* = 1, and Schedule Performance Index *SPI* = 1. This item was completed according to forecasted schedule and costs.
17. *Works that are funded by reserve fund*. In this case this item wasn't initially predicted as it was added completely as an item later, as a binder course with a thickness of t=4cm, because of the changes in the project. Cost Performance Index for these works *CPI* = 0.999, which means that cost of these works is almost the same with the value of the volumes completed, as it changes only with 0.1% less. As for the Schedule Performance Index, that cannot be calculated because if we consider the initial project, it didn't exist as an item at all.

Figure below represent graphs of the results that were taken from calculations of all CV's and SV's of the items of the project *(Fig 25).*

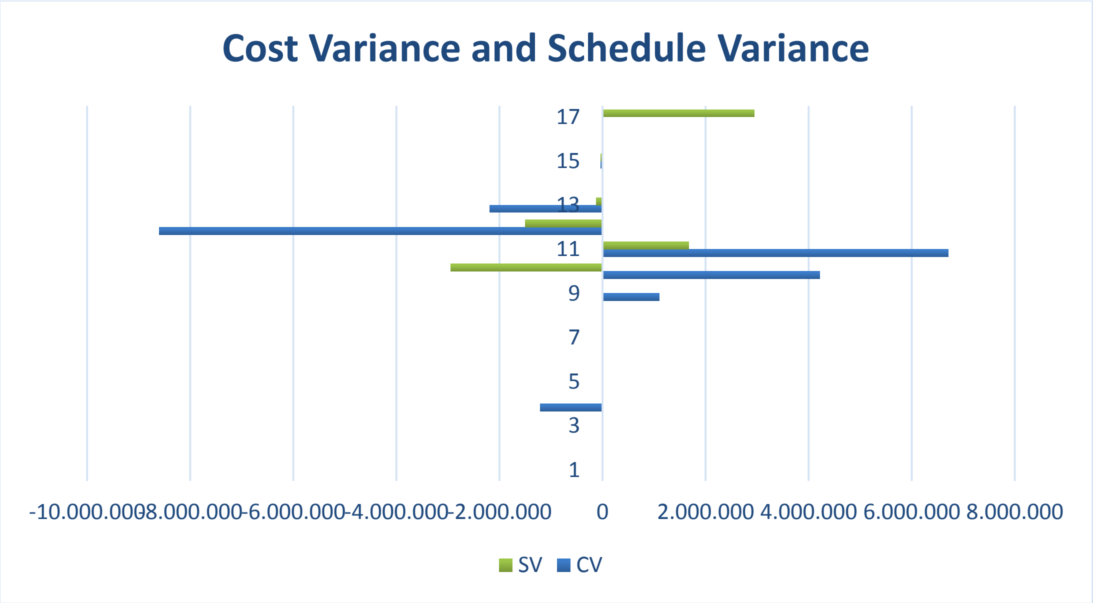

Figure 25. CV and SV Illustrated

Figure below represents Cost Performance Indexes and Schedule Performance Indexes for the whole items of the project. This graph is helpful to understand which items were more problematic and caused the project to be over/under budget or behind/ahead schedule *(Fig 26)*.

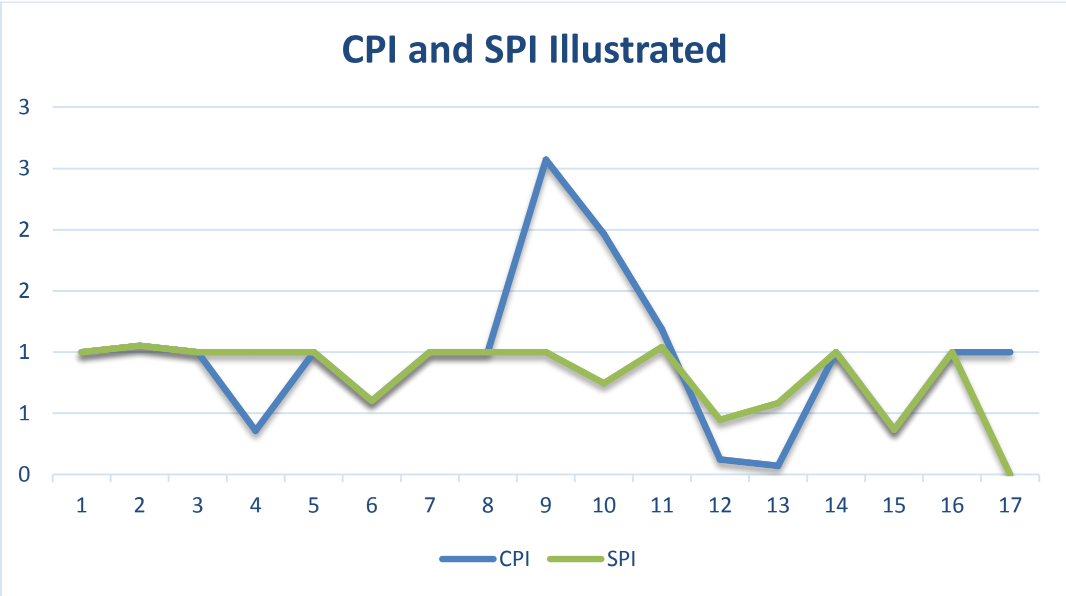

Figure 26. CPI and SPI Illustrated

As a final result there are calculations of the total values of the project. Overall, it can be said that it is completed with a very good performance according to costs and schedule. For the whole project there were found these results: Cost Performance Index of the total project is calculated to be *CPI* =1 and Schedule Performance Index of the total project is calculated to be *SPI* = 1.001. This are some very good results as it means that the costs of the completed volumes matches with the value of the volumes that were actually paid and also the volumes for the total project are completed in the same amount as the forecasted volumes in the initial project. Cost Variance for the total project is *CV* = -2090 Lekë, which means that it is paid 2090 Lekë less than it is actually completed. This is a very good indicator that the earned value was almost the same with the actual costs that were needed to complete the project. Schedule Variance for the total project is SV = 31,650 Lekë, which means that 31,650 Lekë is the difference between the estimated value for the completed works and the planned value. All these results are represented in Table 6 *(Tab 6)*.

Table 6. Performance Indexes of the Total Project

Index	Value
CPI	1
SPI	1.001
CV	-2,090
SV	31,650

Below it is represented the table with the whole calculations for each item *(Tab 7)*. As we can see from the results the project overall has the results of the most favorable case as it was completed within the whole parameters according to costs and schedule.

Table 7. Performance Indexes according to costs and plan

	EV	CV = EV - AC	SV = EV - PV	CPI = EV/AC	SPI = EV/PV
1	2,520	0	0	1	1
2	113,850	5,730	5,730	1.053	1.053
3	43,248	0	0	1	1
4	672,000	-1,202,880	0	0.358	1
5	18,084	0	0	1	1
6	8,670	-5,730	-5,730	0.602	0.602
7	360,000	0	0	1	1
8	1,800,000	0	0	1	1
9	1,800,000	1,100,000	0	2.571	1
10	8,588,443	4,218,043	-2,945,771	1.965	0.745
11	42,430,104	6,705,984	1,679,040	1.188	1.041
12	1,206,000	-8,604,000	-1,494,000	0.123	0.447
13	168,000	-2,184,000	-120,000	0.071	0.583
14	1,242,000	0	0	1	1
15	19,215	-33,390	-33,390	0.365	0.365
16	480,000	0	0	1	1
17	2,945,771	-1,848	2,945,771	0.999	-
T	**61,897,905**	**-2,090**	**31,650**	**1**	**1.001**

4.2 Calculation of Performance Indexes of an ongoing engineering project

The second project that was studied was the project of “Overpass of the train until Mes Road”. This project is a project that is not completed and it is beneficial to this study because it can be studied in a lot of aspects: calculation of the performance of costs and schedule, calculation of forecasting indexes and also calculation of the future performance. This study is done in order to control and verify whether the parameters that were defined in the planning stage match predictions and the values that were declared by contracting company.

4.2.1 Physical and financial advancement of the project

First of all it is calculated the advancement of each works according to the number of the items that are estimated in the initial planning. The project is divided into 6 main parts, and based on the analysis, documents, and physical data that is taken from the technical office of the company, this is the physical advancement of the works at the moment of time T = 382 days (15 April 2016):

1. Reconstruction works – 90%
2. Road Lighting works – 90%
3. Displacement of electric wires – 100%
4. Construction of Electric Cabins – 95%
5. Cable Network – 100%
6. Works that are covered by Reserve Fund – 100%

After doing calculations based on the formula that was presented in the methodology part, the advancement of the works is translated into real values *(Tab 8)*. The method used for finding the financial advancement of the project was “According to the % of the advancement of the works”. This method was used because the project was complex and long lerm. As it can be seen at the moment of time T = 382 days (15 April 2016) There was completed the amount of works that translates in terms of a value of 339,387,087 Lekë, out of 356,756,814 that is predicted to be spent for this project.

Table 8. Advancement of the works

Item #	An = Cn x Wn
1	251,414,573
2	39,744,193
3	792,709
4	14,593,986
5	17,092,275
6	15,749,352
	339,387,087

4.2.2 Calculation of performance indexes of costs and plan

This project was analyzed and studied in the costs of term. This analysis calculates the performance indexes of costs and plan for those works that were completed. After calculating the indexes EV, CV, SV, CPI and SPI for six main items that were part of the project plan, these results were found:

1. *Reconstruction works*. Cost Performance Index is *CPI* = 1.002 > 1. This is a very good result, and it means that the cost of the completed works is the same with the value paid for the volumes. Schedule Performance Index is also SPI = 1.023 > 1. This value shows that there are completed more works that were initially planned. This result is optimal.
2. *Road Lighting works*. Cost Performance Index for this item is *CPI* = 1.649. This means that the cost of the completed work is lower than the value of

completed volumes. This item has a higher cost performance that predicted, where there are completed more works than it is paid. Schedule Performance Index has a result that was rare, because *SPI* = 9.368 > 1. This means that there are completed a lot more works that are initially planned, but it also means that this item has exceeded the deadline and made that the works would extend even more. These results show that this item is completed under budget but behind schedule.

3. *Displacement of electric wires*. The results for the Cost Performance Index is *CPI* = 0.9 < 1, a value which shows that the costs of these works were 10% less than the value of the completed volumes. The results for Schedule Performance Index is *SPI* = 1, this value shows that volumes for these works are completed in the same amount as it was forecasted in initial planning.
4. *Construction of electric cabins*. Cost Performance Index for this item is *CPI* = 0.854 < 1. This value indicates that the costs of these works were 14.6% less than the value of the completed volumes. Also the Schedule Performance Index for this item is *SPI* = 0.95 < 1. This value indicates that there are completed 5% less volumes that were predicted in the initial project. This was the item which had the lowest performance in the project, costs were exceeded compared with volumes committed, and also the schedule of completion was delayed.
5. *Cable network*. Cost Performance Index for this item is *CPI* = 0.78 < 1. This value indicated that the costs of these works were 22% less than the value of the completed volumes. Schedule Performance Index for this item is SPI = 1.001 > 1. This value indicates that there were performed almost same volumes as it was forecasted, and the schedule was exceeded.
6. *Works that are covered by reserve fund*. Cost Performance Index for this item is *CPI* = 1, and Schedule Performance Index is *SPI* = 1.112 > 1. These values show that the project was completed within forecasted parameters of the budget, but lacked in schedule, as it was exceeded the forecasted time and there were completed more volumes that were forecasted in the planning stage.

Figures below represent graphs of the results that were taken from calculations of all CV's and SV's of the items of the project and also CPI's and SPI's of the items are illustrated *(Fig 27, Fig 28)*. It is important to have CV's and SV's illustrated because CV show the difference between the estimated value for completed works with the value that was actually spent when the works were finished, and also SV shows the difference between the estimated value for completed works with the value that was supposed to be spent according initial planning.

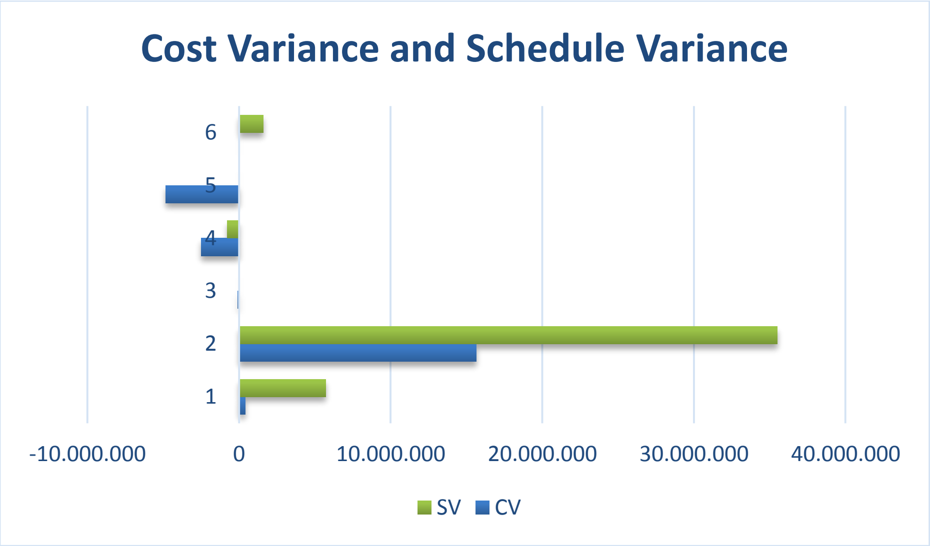

Figure 27. Cost Variance and Schedule Variance illustrated

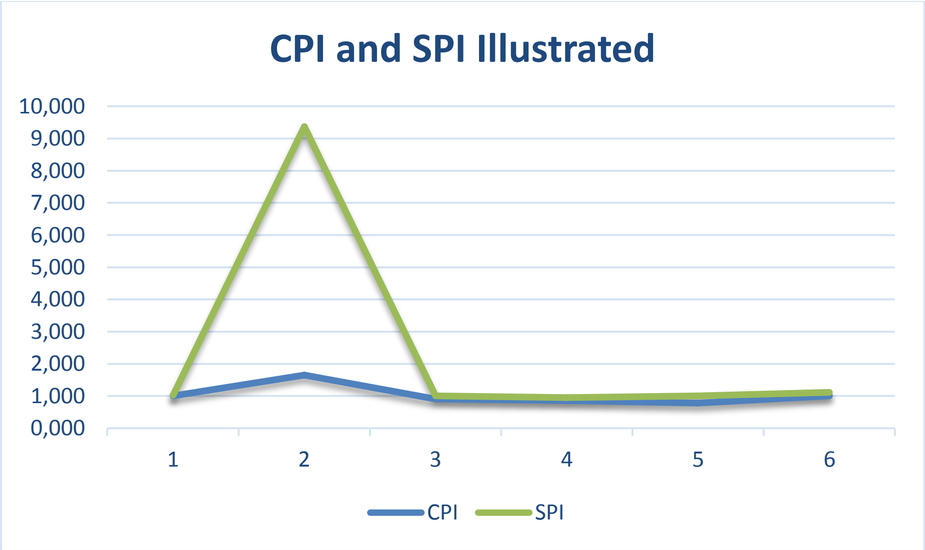

Figure 28. CPI and SPI illustrated

As a final result there are calculations of the total values of the project. Overall, it can be said that it is completed with a good performance according to costs and schedule. For the whole project there were found these results: Cost Performance Index of the total project is calculated to be *CPI* = 1.026 > 1 and Schedule Performance Index of the total project is calculated to be *SPI* = 1.141 > 1.

These results indicate that the project is within all parameters. In the terms of costs it can be said that costs were higher than predicted, with 2.6% more costs than were predicted in the planning stage. This means that there are completed more works than it was actually planned. And also completion of the project is late according to its final deadline.

Cost Variance for the total project is *CV* = 8,650,705 Lekë. This value indicated that it was paid 8,650,705 Lekë more than it is actually completed. Schedule Variance for the total project is SV = 42,052,191 Lekë, which means that 42,052,191 Lekë is the difference between the estimated value for the completed works and the planned value.

Overall it can be said that the project performance according to costs and plan is within all parameters.

Table 9. Performance Indexes of the total project

Index	Value
CPI	1.026
SPI	1.141
CV	8,650,705
SV	42,052,191

Below it is represented the table with the whole calculations for each item *(Tab 10)*. As we can see from the results the project overall has favorable results as it was completed with good parameters according to costs and schedule. This calculation is done based on the advancement of works at the moment of time T = 382 days.

Table 10. Performance Indexes according to costs and plan

Item #	**EV = BAC x Wn**	**CV = EV - AC**	**SV = EV - PV**	**CPI = EV/AC**	**SPI = EV/PV**
1	251,414,573	415,518	5,718,698	1.002	1.023
2	39,744,193	15,647,137	35,501,531	1.649	9.368
3	792,709	-88,036	0	0.9	1
4	14,593,986	-2,494,058	-768,105	0.854	0.95
5	17,092,275	-4,829,856	9,520	0.78	1.001
6	15,749,352	0	1,590,547	1	1.112
T	**339,387,087**	**8,650,705**	**42,052,191**	**1.026**	**1.141**

4.2.3 Calculation of Forecasting Indexes

In order to find out the total value of the work that has to be completed and the total value of the project at completion, and also the variance at completion, there are made calculations for each item of the project. Table 11 presents the results below *(Tab 11)*.

Table 11. Forecasting Indexes for each item of the project

Item #	**EAC= BAC / CPI**	**ETC = EAC - AC**
1	278,887,839	27,888,784
2	26,774,506	2,677,451
4	17,987,414	899,371

1. *Reconstruction works*. For the first item Estimation to Complete is ETC = 27,888,784 Lekë, which is the value needed for the remaining work. Estimation at Completion is EAC = 278,887,839 Lekë which is the total value until completion of these works.

2. *Road Lighting works*. For this item Estimation to Complete is ETC = 2,677,451 Lekë, which is the value needed for the remaining work. Estimation at Completion is EAC = 26,774,506 Lekë which is the total value until completion of these works.
3. *Construction of electric cabins*. For this item Estimation to Complete is ETC = 899,371 Lekë, which is the value needed for the remaining work. Estimation at Completion is 17,987,414 Lekë which is the total value until completion of these works.

The items *"Displacement of electric wires"*, "*Cable network"* and "*Works that are covered by reserve fund*" are completely finished and there can't be any calculations for forecasting indexes.

Table 12. Forecasting Indexes for the whole project

EAC_{total}	ETC_{total}
347,663,369	**16,926,987**

After doing calculations, the total value of the remaining works is ETC_{total} = 16,926,987 Lekë. Total value of the whole project until its completion is calculated to be EAC_{total} = 347,663,369 Lekë.

As it can be seen, the project, if it is completed by this calculated performance, at its completion it will not pass the estimated value, but it will be VAC_{total} = 9,093,445 Lekë. This value shows that the budget predicted for the project will be more than enough for the completion of the project, so the project will be completed under budget.

Table 13. Variance at Completion

Value	Lekë
Recalculated, EAC	356,756,814
Initial Planning, BAC	347,663,369
Difference, VAC	**9,093,445**

4.2.4 Calculation of Final Change of Schedule

Firstly the project was calculated to last 245 days. Then with changes in the project and various reasons, the project was planned to be finished in 412 days. After doing calculations, in the moment of time T = 382 days, the Final Change of Schedule is calculated to be CS_f = 528 days. This means that the works according to recalculated estimation will end 116 days past its final deadline.

4.2.5 Calculation of Future Performance Indexes

Future Performance Index is also calculated and the Future Cost Performance Index is CPI_{future} = 0.65. This value shows that to reach the estimated cost value for the completion of works, in the future there should be implemented works with a value of 65 lekë for each 100 lekë spent, in order for the project to be inside the monetary borders that were defined in the estimation, by not violating the quantity and the quality of the works.

Table 14. Future Cost Performance Index

$\mathbf{CPI_{future}}$
0.65

CHAPTER 5

CONCLUSION

5.1 Conclusions

The study that was developed in this thesis has implemented all the advanced methods of management and control of engineering projects, for the two infrastructure projects of “Kiri Bridge – Mjedë” and “Overpass of the train – Mes”. This study highlighted that:

Albania is a country that is still in transition, and being so the rules, regulations, norms and procedures that are followed for management, monitoring and control of these projects, do not match with the best international practices. This increases the scale of uncertainty and quality of implementing engineering projects according to required standards. Engineering projects, being unique and not repetitive have a high scale of uncertainty in fulfilling the objectives defined in technical project and during their planning stage. Even though there is a lot of room to improve, both engineering projects that were studied in this thesis, were managed in a sufficiently good manner, according to costs and schedule.

The planning stage is the stage that has the most problems in the cycle of execution of engineering projects. The deficiencies in this phase, cause the main deviations in the project, regarding to fulfilling the project’s objectives. Also the quality of technical projects of these infrastructure works is the main factor of failure of the planning stage, and eventually the whole process of their construction. In these technical projects there are identified these main deficiencies:

- Inconsistency of project quotas with terrain quotas.

- Low detailing in longitudinal sections and cross-sections.
- Changing of grade lines and geological problems that represents the terrain where the body road passes.
- Determination of technical details of the works of art, the walls and the contours of the road, in particular with regard to irrigation and drainage canals that accompany this road axis in its entire length.
- Technical solutions in regard with the network's displacements and also the water supply pits.

All these deficiencies made the calculations of the estimated quantities and volumes to not be accurate and to not match with the real situation in the site. This incorrect planning caused for the projects to be revised and changed. These changes of estimates and the technical projects are the main reasons of decreasing the cost and schedule performance of the projects. Concretely, by taking off from the estimated value those works that have a low/high price and by adding those works that have a high/low price, there is created a difference between total volumes of the two estimates, where the total value of them remains the same but quantities and volumes decrease or increase (depending on the case).

By calculating performance indexes according to costs for the project of "Kiri Bridge – Mjedë" where *CPI* = 1, and for the project of "Overpass of the train – Mes" where *CPI* = 1.026, there is indicated that the costs of the projects is equal to the value of the completed volumes of the works for the first project, and less for the second project.

By calculating performance indexes according to schedule, for the first project where *SPI* = 1.001 and for the second project where *SPI* = 1.141, there is indicated that there are completed more works than there are predicted in the initial planning, so the costs will be higher. Also this indicates that there are changes in the final deadline, because an inaccurate calculation of the volume of the works in the planning stage has brought an inaccurate deadline for the completion of the project.

Application of the Earned Value Method for calculation of cost and plan performance indexes *CPI* and *SPI* during the implementation of engineering project, makes it possible to monitor and control the most important parameters of an engineering project. Calculation of performance indexes provides a quantitative evaluation of the performance of infrastructure works in the terms of costs, quantities and schedule. This method, through calculation of performance indexes of cost and schedule, *CPI* and *SPI*, and future performance indexes, CPI_{future} determines the performance of the project in a fixed moment of time T and the necessary performance in the future for the completion of the project based on the estimate value and volumes, by not violating quality. Also, based on these indexes it is calculated the deadline of the completion of these works.

Earned Value Method is an efficient tool, which by using the performance indexes makes proper corrections of the digressive data of the realization of engineering projects, by turning these data into accurate and reliable data.

5.2 Recommendations

Based on the results of this study and in the above conclusions, for increasing of the quality and efficiency of the management, monitoring and control process of engineering projects, there are some recommendations that are proposed:

1. Before starting of the implementation of an engineering project there should be build the Process Flowchart of Construction works, based on all the elements of it.

2. After this there should be built the Work Breakdown Structure (WBS) and also Organizational Breakdown Structure (OBS), which are responsible for creating optimal conditions for distribution of project resources (schedule, budget, people) and also the increasing of the efficiency of the processes.

3. The planning of the deadlines should be implemented according to Critical Path Method (CPM) and also Program Evaluation and Review Technique (PERT), which are responsible for defining the critical ways of the construction process and also for time. In this way it is done the optimal calculation of the deadlines for each construction activity.

4. Application of the Earned Value Method for calculating the performance indexes of the project in each moment of time Ti and also calculation of the future performance indexes, where its use during the process of monitoring, controlling and auditing, would bring:

- Evaluation of the real physical advancement of the project.
- Evaluation of the performance of an engineering project based on technical and economic criteria that are set according to initial planning.
- Giving recommendations to implement a real calculation of the completion of the works.
- Quantitative evaluation of the findings in costs and schedule.
- Fulfillment of corrective actions.

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