Loughborough University

INTEGRATED COST MANAGEMENT SYSTEM FOR DELIVERING CONSTRUCTION PROJECTS

By

Thomas F. Theodorakopoulos

A thesis submitted in partial fulfilment of the requirements for the award of the degree Doctor of Philosophy (PhD) of Loughborough University

31/01/2017

ABSTRACT

Cost management forms a major discipline in delivering construction projects of different sizes and complexity. Traditional cost management systems are mostly based on principles enacted several decades ago. A notable feature of these traditional cost management systems is that key information required for critical decisions is usually produced too late, and is often too aggregated and configured in a form that is not amenable to the requirements for current project management practice. Other problems associated with traditional cost systems relate to inadequacies in estimating and cost control processes and particularly the lack of integration of cost management across the whole project. The lack of integration means measurements provided by traditional cost systems do not sufficiently align with the goals and objectives set for the project. To address these inherent weaknesses in the current practice of cost management, a number of studies have argued for an integrated alternative that better responds to the information demand and decision making need to be developed. The thesis presents the development of a solution to such an integrated cost management system. The developed solution addresses the gaps of the traditional option by integrating the stages making up the whole life cycle of the project to enable professionals gain an appreciation of the ramifications of any early decisions made. The investigation conducted to support the development of the integrated cost management system and the applied model addresses user requirements and determination of the system boundary conditions for efficacious use by key decision makers.

The new cost management system developed achieves a linkage of the planning and control stages into one, with a continuous stream of cost management information in both stages. The integration ensures that cost information is more relevant to the circumstances of the modern project manager.

Keywords: Cost, Management, Project, Estimation, Control, Integrated System

DEDICATION

I dedicate this work to my father, Filippos, my mother, Sophia, and my brother, Giannis, for their parental and family love and care, and for being the foundation and pillars in my whole life. Whatever I have done in my life would never have been accomplished without them. I owe them everything for the past, the present and the future. Their encouragement and unconditional support in all my decisions has always been the power I use to carry on.

“Dad, Mum, Gianni, I am grateful for everything, you are my only red line in this life”.

ACKNOWLEDGEMENTS

I went through lots of challenges, risks and tribulations throughout the period of study that has culminated in this thesis. It was an extreme adventure for years with personal and external difficulties attending my research ‘journey’. All these difficulties presented challenges that in the end have made me a better person in my moral standing, and with a better personal ethical code. Moreover, apart from the knowledge gained, there is also a realization that I have developed into a complete person, and become closer to people I care about, and those who care about me.

I would like to take this opportunity to express my sincere gratitude to my Supervisors Dr. Francis Edum-Fotwe and Professor Andrew David Freeman Price, whose trust, support and guidance went far beyond their job requirements. I believe in them and I trust them in everything from now on. Their support has been unique, and they knew how to manage my situation and how to make me carry on with the research study. Words cannot fully express what they have done to assist me.

I am also grateful to Professor Christine L. Pasquire who was my initial supervisor and was at the starting point of what I have done later in the research. She supported me to be innovative, and I am grateful to her for our initial co-operation.

I would also like to thank the Dean and staff of the School of Civil and Building Engineering, who have supported my development, including those not in the limelight, who arranged facilities and premises and always found me solutions to my every inconvenience for all these years.

My appreciation and warmest gratitude also go to a man who has been beside me for over fifteen years now, through his friendship and acting as my ‘guardian angel’ since we first met in UK. Mr. Don Collie is the one who has been my ‘bulwark’. He has seen me at my best and worst, and listened to my regular expressions of ‘fears and concerns. I owe him so much. Because of you Don all my impossibilities have become possible. I cannot thank you enough.

I owe special thanks and debt to my girlfriend Stavroula and her brother Christopher for their unique support in all aspects of my life and their understanding and help all these years to complete this research study. They kept me balanced when things were wrong and their support made me put my life back on track. Thank you both.

I would like to take this opportunity to extend my appreciation to my work colleagues in Greece for their kind support over all these years. I want to make particular mention of Mr. Skeberis Evangelos, the Director of the Project I am part of, whose guidance, clear opinion and knowledge in the many discussions we had, was a compass to me, even if we disagreed on some occasions in our deliberation of the issues pertaining to this research. Without his insight and open-minded attitude, possibly this research would never have been completed.

I would also like to acknowledge the exceptional contribution by Mr. Nikos Christoulas, Deputy Project Director in the Construction Joint Venture “Apion Kleos”. His innovative approach to the management of construction, as well as his global experience and awareness of construction delivery and projects in general, was essential for the system specification. I really thank him for his support.

I also owe thanks to my colleague Andreas Stasinopoulos, Mechanical Engineer of the Motorway Project, whose input was invaluable for conducting the research. Thank you Andrea.

I would like to express my heartfelt thanks to my uncle George and aunt Chara, and my lovely cousins Vassilis and Helen, who always believed in me.

Finally, there are many others who have not received a mention here but one way or the other were close to me and part of my life during this PhD journey. Please accept my most sincere thanks.

At last I would like to express my highest appreciation to my maternal and paternal grandfathers and grandmothers, who are not alive but their lives were, are and will be a lighthouse for me. Thank you all for being the ‘beacon’ of my life.

Thomas

Table of Contents

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND

For most clients in construction the management of projects is synonymous with the management of costs, as that impacts directly on the funds they need to mobilize to deliver their scheme. The cost consideration is especially pertinent for large construction schemes and projects, where the risks and complexity factors are high. On such schemes, project managers often have a huge challenge to deliver operational tasks, as well as forecast probable overruns and delays due to changing conditions of those complex factors. Effective management of costs in such project environments is a key role and often a requirement for achieving successful delivery, and is often the leading criterion for key project decisions (Watkins, 2014). The evidence from practice suggests that such effective management of cost is often difficult to attain (Gillet, 2015). The use of contingency sums, which is prevalent in construction, is a tacit recognition of the inadequacy in effective management of cost. Recognizing the limitations of current practices in cost management within construction, Qazi et al. (2016) argue for a new approach, and suggest that the need for such a solution is more essential now.

Construction projects involve significant levels of uncertainty and risks that exist throughout the project life-cycle, and present cost implications for the client and other stakeholders. Some of the uncertainties stem from factors such as weather conditions, soil conditions, client changes, design changes, changes in economic conditions, and the interaction between multiple operations or changes imposed by organizational interfaces. According to Salem et al. (2006), these factors are additional to the actual works, and can produce unique circumstances that could be as critical as the planned activities, and have a significant impact on project cost. Effective management of cost requires awareness and accounting for these additional factors.

The management of construction projects requires knowledge of modern management as well as an understanding of the design and construction process (Edum-Fotwe and McCaffer, 2000). Construction projects have a specific set of objectives and constraints, and project cost management is listed as one of the core areas that a project manager should be competent in (Akintoye and Fitzgerald, 2001; Project Management Body of Knowledge Guide, 2013).

In today's environment, a significant number of organizations and companies operate cost management systems that were developed two or three decades ago (Afetornu, 2011). The transactions and functioning of these systems are typically based on the workings of the industry as it was then. Many of the bottlenecks associated with the inadequacy of cost management can be attributed to the use of such systems. It is therefore, not surprising that the traditional approach employed by these companies for managing costs in today's industry leaves many a contractor and a client dissatisfied with the cost performance of their projects (Thorpe et al., 1992).

Typically, cost management methods adopt the principle that the final cost of a project is driven by the design solution, without the cost function serving as part of the criteria for acceptable designs. As a consequence, the cost management function has attempted to exert control only after budgets are fixed. According to Pennanen (2011) such an approach to costing often involves taking action to recover or conform to unrealistic cost targets instead of contributing to the preparation of acceptable and cost-effective design solutions.

The problem of cost management in construction is made more complicated by the practice whereby the company that controls the cost is different from the company that prepares the cost estimates or project budget. It is therefore not uncommon to find that the techniques, basis, and software environment employed for the estimates differ between the ones employed for budgeting, and those which are utilized for the control function (McCaffer and Baldwin, 1984). According to Afetornu et al. (2006), such a situation in construction persists because often the client, the contractor, and the subcontractor all rely on different software solutions, which are often affected by interoperability restrictions imposed by software developers. Essentially, each company in the supply chain has its own functional operating system for cost management. Therefore, it is not uncommon to find that two or more cost management systems are used and operated for the same project. Project solutions such as that of Terminal 5 development at Heathrow, that took advantage of a Common Data Environment, and a standardized software suite to support the delivery of the whole project, are an exception rather than the rule in construction (Antoniadis et al., 2006).

Furthermore, Sahle and Dinku (2016) suggest that the lack of integration between the initial estimation stage and project control is the cause of many problems such as cost overrun, schedule delay, lack of quality attainment. These adverse outcomes often lead to loss of efficiency, productivity and performance of any traditional cost management system as well as a general lack of constructability for a project. Uher (1996), emphasizes the effect of the adverse outcomes by suggesting that projects are often completed over budget and delayed because of a lack of attention to the important aspect of *effective integration*.

Ordinarily, having a natural inclination towards the adoption of innovation could help to address some of the constraints deliberated upon in the sections above. However, Garg et al. (2003) reported that companies are generally slow to implement new tools even though such tools, in many cases, have the potential to enhance their competitiveness. They further argued that there is an established consensus that cost systems are not providing accurate information due to a lack of integration. Doloi (2011) indicated that the lack of integration persists today, and suggested that organizations are loath to adopt new tools and techniques in cost management because of economic realities and internal resource constraints, as well as the difficulties involved with changing familiar practices.

In practice, most firms display a preference for using traditional accounting and cost systems even though their faults and limitations are well known (Innes et al., 2000; Garg et al., 2003 and Jallow et al., 2014).

A cost management system is regarded as a framework for the administration of project cost information. Typically, the system would consist of a set of principles, methods and tools whose main objectives are to estimate costs and to generate information in order to support different managerial decisions during the distinct phases of a project. Cost management systems are expected to be dynamic, proactive and able to support different decision-making processes, as well as make a contribution by minimizing the adverse effects of uncertainty. In the construction industry, Kim (2002) and Project Management Institute (1996) make the particular emphasis that cost management systems must include the processes required to ensure that the project is completed within the approved budget. As such, the cost management must no longer be used as a functional solution that is employed post design, but should provide a systems solution that brings together, and affects, all the participants involved in the process of delivering the project.

1.2 RESEARCH PROBLEM

The foregoing discourse on the viability of the traditional techniques and methods provides a basis and defines the need for a different approach to cost management to better respond to the requirements of modern project delivery (Forbes and Ahmed, 2011). Such a new approach would require establishing new foundations for managing costs and at the same time facilitate more reliable cost comparisons. The rationale for such a new approach would be to overcome the shortcomings in current offerings of cost management solutions that present a suboptimal resolution of the information required to support the efficient delivery of projects. The suboptimal performance can be associated with the lack of integration between the cost estimation from the various phases of the design activity, and the planning and control processes which are currently separated for most construction projects. The proposal, on which this thesis is based, is that the integration of the two stages into a common cost management information system should help to overcome the current concerns. This can be achieved in an environment whereby there is a dynamic operation of the features of integration on the one hand, and feedback control and analysis on the other. Such a connected approach will help organizations and companies to be more inclined to adopt the new integrated system as the financial benefits would be more obvious to them.

Within the construction sector, it is customary for architects to work with clients to establish what they want, and then produce facility designs in response to the client's requirements. When the cost of those designs are estimated, more often than not, they are found to be greater than what the client is willing or able to bear, requiring designs to be revised, and then re-costed (Jallow, 2014). This cycle of the design estimate procedure can be run several times, and is wasteful and reduces the value that clients could derive for their money. According to Ballard (2006), this approach to establishing development cost has created a situation whereby the outcome of adopted solutions is based on a *Design-led* rather than a *Total Value Design* (TVD) approach that treats costing concurrently with the evolution of the design solution.

In most construction projects, traditional cost management is seen as comprising separated estimation techniques on the one hand, and cost control procedures on the other. Since the two critical cost-related activities are mostly prepared by different people and in different companies, the traditional approach often leads to a greater cost of design than that which is estimated at the pre-construction phase. Such greater cost does not benefit the client. As shown in Figure 1.1, when the design cost increases the relative value of the project to the client is reduced.

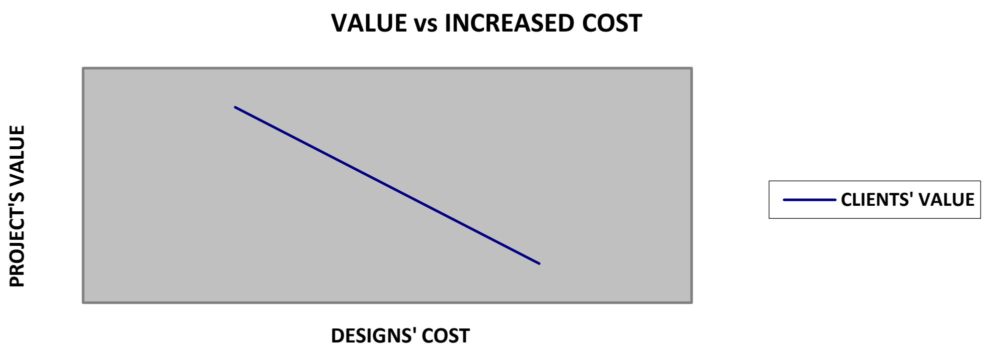


Figure 1.1: Value of Clients' money vs Costs in Design (Source: Author's proposal)

As such, the current approach to establishing and managing costs can be deemed inconsistent with the ethos of efficiency that cost management aspires to.

Kern and Fermoso (2000) further elaborated on the shortcomings of the traditional cost management systems as having three important consequences for the delivery of projects in the construction sector. Firstly, such systems cannot provide reliable forecasts of project cost. This is because costs are distributed to the project in a simplistic, deterministic and arbitrary way that usually does not represent the real-life situation in the delivery of the project. Secondly, they fail to stimulate or suggest solutions in decision-making policy throughout the project's lifecycle. The derived reports of traditional systems provide simplified data and information that provide little help to the managers who have to rely on such information for the decision-making on the progress of projects (Soibelman et al., 2011). Finally, the cost management information provided by traditional systems is of little help to managers in their effort to improve project performance. These limitations of traditional cost management are recognized by other researchers. For example, Ostrenga et al. (1997) described the main problems and limitations that have been identified with the poor performance of traditional cost management systems as relating to: flaws in estimating and cost control processes; inadequate information for modeling; and a lack of integration of cost management.

In addition, Kern and Fermoso (2000) argued that the measurements emanating from traditional cost management systems are not linked to the goals and objectives set for each project. This is because those systems have their own internal functional operation and that they present considerable complications in adjusting to the unique and often one-off circumstances of the project. Moreover, traditional cost management approaches are limited in their ability to provide solutions that adapt to the complex setting of today's projects because of their functional simplicity and constraints (Doloi et al., 2011). Doloi (2011) argued further that most of their limitations are due to the two factors elaborated below.

- They rely on many initial assumptions which often run against the reality of delivering the projects, providing as a result various cost management models which fail due to the use of bad or misleading parameters.
- They are not capable of capturing the inherent non-linear behaviour of the project's data. There is evidence that many cost-related decisions in the project environment reflect a non-linear distribution and therefore, applying traditional cost management techniques, which basically follow the assumption of a linear approach, would consequently provide sub-optimal solutions.

Managing Costs is a subject that has increased in interest over the years, both among academics and professionals. Alongside this growth, a significant level of scepticism has developed in how adequate the traditional cost management systems are for solving today's project delivery (Olawale and Yakubu, 2015). This is due to the fact that the economic environment today affects the construction industry in a way that involves more information and solution options for solving its problems.

Traditional cost management practices and processes provide inadequate and less reliable estimates, and therefore they fail in helping managers achieve effective decision making in delivering the project.

Among the main drawbacks related to traditional cost management approaches are described by Ballard et al. (2002), who mention that costing approaches and traditional systems mostly require an excessive cost in individual effort and jobs.

Ballard (2006) subsequently argued that costs are driven by other variables rather than the value of the final product (project). For example, the assumptions made in the initial stages of the development can lead to fundamental gaps in the execution of the adopted solution.

In the construction sector, the traditional cost estimating approaches are used in both linear and non-linear environments. Their limitations in both the linear and non-linear environments are based mainly on the assumptions in the initial stages, and on the very complex nature that underpins today's demands for the delivery of projects (Koskela, 2000). Besides the foregoing drawbacks, traditional cost estimating approaches have a narrow parameterization environment, and hence the return of incomplete detail to support the wider functions of project managers.

As a consequence of the influence that today's economic and social environment has on real projects, it has become more and more difficult to predict project out-turn characteristics by relying on traditional approaches only. In one sense, it can be argued that the traditional approaches appear to be less amenable to the effective resolution of the problems presented by today's project, and to provide any policy guidance for decision making of managers (Shillinglaw, 1989).

About two decades ago, Glad and Becker (1996) suggested that an effective cost management solution should incorporate a cost estimating system and generate essential information that addresses the following criteria as minimum requirements.

It should provide a multi-dimensional focus on a multiplicity of cost *objects* such as customers, products, services, functions, processes and activities. Contrary to this requirement, traditional cost management systems are not able to focus on multi-dimensional needs of the project and the project's cost relations.

It must focus to a lesser extent on cost tracking and reporting and more on cost planning and control. This is in contradiction to the traditional approach, in which planning and control cannot be connected or integrated, and thus great effort has to be expended in cost tracking and reporting.

It has to support every key business decision, including sourcing, pricing, investment justification, efficiency and productivity measures, product and process elimination, and new product introduction or technology adoption.

The Glad and Becker proposal holds the prospect of improvement of cost management and the possible elimination of the root problems associated with current costing practice. Adoption of their proposal can therefore facilitate the mitigation of unfavourable cost practices and help eliminate many of the limitations they present in the cost management of projects.

Akintoye & Fitzgerald (2000) derived from a survey they conducted that the absence of an integrated cost management system was prevalent in the UK construction industry. The lack of integrated options has persisted till today. Coincidentally, a wide range of research investigations within the literature focus on and reinforce the traditional approaches instead of moving the improvement agenda towards the integrated solutions proposed by Glad and Becker (1996). Hanid et al. (2011) argued that the persistent focus on traditional practice as the avenue for improvement efforts in research can be attributed to the extensive use of traditional cost management approaches in today's industry by construction companies.

The question that such persistence with the traditional approach by industry raises is the exact raison d' être of integrated cost management for organisations involved in the delivery of projects.

If one accepts that it is to serve the information needs of the design process in an endeavour to facilitate design decision-making by the client and designer, then cost management research to date has failed to focus on an issue fundamental to its existence; namely, communication. The failure can be deemed to transcend the requirement of the design function to include the effectiveness of the cost planning and control environment within which cost management occurs, as well as the communication-facilitating ability of cost models in the formulation of cost estimate messages.

More specifically, research must be directed toward the communication needs and patterns that constitute the "cost planning and cost control process", and the extent to which current cost modelling philosophies satisfy those needs. The Knowledge Guide (PMI, 1996) suggests that adopting such a direction in research will necessitate: an examination of the design process; the information needs of various participants involved in generating the design solution; the nature, availability, and communication of information to facilitate cost modeling and price forecasting; the characteristics of cost methods used by consultants; and the effectiveness of cost methods as parts of a process for facilitating the communication of cost estimate messages.

The fundamental argument here is that improvement in cost management systems should transcend simply the cost function and draw on additional factors pertaining to the overall management of the project. These additional factors will include, but not be limited to, the following:

Addressing the project needs instead of the design solution needs only;

Effective estimates that lend themselves to more effective use for operational control purposes;

Resolving the conundrum of whether to focus on an overall decision-making policy for the project or to focus on the decisions on the design solution; and

Resolving the conflict of providing estimates as products or making estimations more beneficial to the whole project delivery.

This set of general issues raised above can provide the foundation of a response for a new approach that will:

- overcome the day to day problems within a project;
- provide a clear and substantial picture of the progress of the project;
- connect and provide an implementation protocol for the two main processes in project cost management;
- achieve harmonization of the estimation and control process; and
- accommodate as much human input as is required for any integration process.

1.3 RESEARCH QUESTIONS

The foregoing discussion raises the following central question in relation to the management of cost in the delivery of projects within the construction industry.

Is it possible to develop a cost management solution that integrates the conceptual phase and the control of the execution phase, along with the essential costing information for executive decision-making to support the delivery of the project, and also offer a more reliable and user- acceptable alternative to the orthodoxy?

Inherent in this principal question are subsidiary questions that would have to be addressed in order to respond well to the problem of integration for project cost management. These subsidiary questions are:

i. What are the parameters needed to support such an integrated cost management system?
ii. What is the nature of the environment that can support the integration process, which is a dynamic process that supports feedback procedures throughout the life cycle of the projects?
iii. What will be the reliability of such an expanded parameterization for the cost function?

Collectively, these questions provide the framework for the methodology that would have to be adopted to develop an integrated cost management system, and form the basis of the aim and objectives of the study.

1.4 AIM AND OBJECTIVES

In response to the primary research question, the principal aim of this research is to investigate and establish the essential features of, and provide a prototype development and trialling of, a cost management system which *integrates* the planning and control stages for the delivery of projects in the construction sector.

The integrated cost management system should enable the identification and resolution of the problems of poor connectivity that predominates in the use of the traditional cost management methods.

In order to achieve the aim of this research, the following objectives were pursued:

1. Establishment of a current knowledge base that supports the study to include cost management, integrated systems development, and project information planning as well as existing practices related to cost management, cost estimation and cost control techniques.
    - The scope of the review covers construction as well as other engineering disciplines.
    - The review also includes current developments, techniques and solutions in construction by drawing on established, and more recently, digital solutions that are becoming commonplace in construction.
    - The review also identifies analytical approaches to traditional, as well as current, gaps and limitations in the deployment of cost systems and methodologies.
2. System requirements analysis and data collection work to obtain the data configuration for the integrated system development (inputs, outputs, channels). This objective also covers the investigation and elaboration of a detailed analysis for the system components required to support the development of the Integrated Cost Management System.
3. Development of a prototypical version of the Integrated Cost Management System. The deliverables in this objective also cover:
    - Establishing the conceptual form of the Integrated Cost Management System and its variables;

- Providing a System Architecture optimized to enhance the functionality of the adopted design solution;
- Integrating the System prototype and Project Information System (PIS) environment for the new development.

4. Coding and developing the application for the Integrated Cost Management System.
5. Parameterization of the system in compliance with case studies. All system variables need to be parameterised within the software with the purpose of enhancing their effect and range within the application of the Integrated Cost Management System.
6. Providing a set of recommendations for the use of the new system.
    - The Integrated System consists of specific subsystems and variables and an internal mechanism. The objective includes creating a guidance and system support, which can be employed to configure the level of integration for the subsystems making up the Cost Management System.
    - Guidelines on, and instruction for, using the Integrated System and a system users' vocabulary for clarification of the system functionality.
7. Testing and validating the Integrated System.
    - The developed Integrated Cost Management System for Delivering Construction Projects (ICMS-P) from this research will be tested and validated with data from a real-life project.

1.5 OUTLINE RESEARCH METHOD

The method that underpins this research reflects two complementary elements. The first element is a response to how the research has been designed to address the philosophical aspects of investigation; and the second element is the detailed description of the steps involved in the development of the proposed Integrated Cost Management solution. The first element identifies and critically analyzes essential literature and culminates in the overall research design and implementation. It also provides coverage of the fundamental philosophy that underpins the key data collected to support the boundary conditions and key features of the ICMS-P. Creswell (2013) argues that the appropriate methodology selection should be chosen based on the nature of the research, the objective function of interest and the data required resolving the problem implicit in the study. The second element explains the adopted method for the development of the model by covering the system architecture, configuration, coding, verification, and validation of the process involved.

The adopted philosophical approach, the research strategies, the form of reasoning, the research application approaches, the research objectives, and the data collection process and case studies, all are defined as founded on the positivist school of thought.

1.6 SCOPE OF RESEARCH

It is important to point out that attempts at improving traditional cost management started the 1960s. Such efforts included the idea of using operational techniques for cost estimating. At that time, Skoyles (1965) discussed a radical change in traditional cost estimating methods that was proposed in the U.K. in which a very detailed estimate of the project was produced based on the early definition of construction methods.

The literature review conducted to support this work has produced a theoretical basis and key principles involved in the process of managing costs in project delivery.

This research addresses not only the need to move towards a new integrated solution for managing cost information in project delivery, but also provides a demonstration of the proposed solution as it is reflected in practice by the development of a prototype. The proposed innovative solution has been achieved by focusing on the origin of the problem, i.e., the traditional approach of delivering projects, in order to set up a comprehensive mechanism with inputs, outputs and operational procedures that provide an optimal response to the main question that is currently confronted by the construction industry. Principally, how can the construction industry become more efficient at delivering projects with greater transparency to overcome information bottlenecks currently experienced at the planning stage, the effects of which permeate throughout the delivery process. A common case of such transparency is the reliability of targets set at the conceptual phase, based on a different set of assumptions for the effective delivery of the subsequent phases.

The new integrated cost management system overcomes the gaps of the traditional approach by integrating all the key stages making up the project process. The integration transfers data and valuable information in a continuous dynamic process, which helps to improve the estimation as well as the control process, and through such dynamism increase the overall performance of any project. At the same time the proposed system will support the provision of feedback in all the stages including the control stage. The stages that this research analyzes are the inception, design, installation and use/operation stages.

As such, the integrated cost management system provides a proactive means for project control that seeks to make cost a driver for design, thereby reducing waste and increasing value. Under this new approach, the estimation and the control stages are integrated and share the same goal of maximizing the overall performance and value of the project (Ballard, 2006)

1.7 ACHIEVED OUTCOMES

The proposed integrated system was accomplished by dividing the development into work packages that are connected with the objectives of the research as follows:

A. Analysis, categorization and presentation of requirements needed to develop the integrated cost management system within a lean process;
B. Investigation of the variables and information associated with the characteristics of the proposed solution by using PIS, ERP and EPP systems along the life cycle of the proposed integrated cost management system;
C. Development of the prototype framework of the requirements for the new integrated cost management system within a project delivery context;
D. Review of both contractor-side and client-side practices to highlight the differences in requirements that should be captured within the system;
E. Development of a prototype of the integrated cost management system;
F. A study involving the application of the prototype by modeling the ICMS-P with a real-life project; and
G. Validation of the ICMS-P.

1.7.1 Key Achievements

From the significant accomplishments of this study arise the following key points:

- Traditional cost management approaches are limited in their support for integration of the cost management function.
- Investigation and analysis of Cost Management System Framework requirements within the project delivery process exposed conflicts in the use of, and configuration of, information required for decision making at the various stages of a project.
- A definition of the internal mechanism making up the process of cost management was reached.
- A new prototypical integrated cost management system as an open shell that can be deployed by configuring it to different project types and contexts was developed.
- Application of the development system to a real project to demonstrate its efficacy for achieving the set requirements was carried out.

- Application of the system to different structures of a project to demonstrate how comprehensively it addresses cost information requirements in the modern project was carried out.
- Recommendations for other systems' development related to more specialized constructions were proposed.
- A relevant cost database to support the exploitation of the new system, which has relevance for contractors, clients and other researchers was developed.

1.7.2 The integrated system (ICMS-P)

The proposed solution presents a unique integration of both planning and the control stage in a new cost management system linking the two processes into one continuous stream of cost management information and feedback between the two stages.

To the important question of 'What makes the integration process so important and useful in the delivery of a project?' two dominant points come to the fore: the first concerns the response to reliability of how the project will be delivered, with what cost and what resources; and the second concerns a resolution of the managers' dilemma of how they will control cost from inception (estimation stage) through the construction (control stage).

The integration achieves a transfer of data and valuable information in a continuous dynamic process, and thus improves the estimation and control process. Further benefits of the achieved development relate to its potential adaptability to other contexts, as well as flexibility in its configuration. For instance, the system can be configured to provide feedback in all stages, including the control stage. Also, the integration methodology that has been adopted in the proposed system covers the project stages from inception to operation stage. However, it can be extended both ways beyond the stages addressed in the study to provide a more holistic solution that can support both project and company requirements.

1.8 GUIDE TO THE THESIS

This section presents a summary of the contents the thesis derived from the academic research conducted in the study. It covers all the research packages implemented starting with the initial hypothesis, the aim and objectives, the literature review, the methodology conducted to achieve the objectives, the system development and the applied model development and its application and contribution to the project’s delivery. A brief description of each chapter is given below.

Chapter 1: The introductory chapter gives a general overview of the research. It justifies the logic behind the research. It describes the aim and objectives and the scope of the research, together with the benefits and outcomes.

Chapter 2 is the first of the literature review chapters, which provides extensive and critical analysis of traditional cost management approaches and the management of contemporary projects and project costs.

Chapter 3 is the second literature review chapter. It describes aspects of cost management in the delivery of a project, together with constraints and the need to improve the whole cost management process.

Chapter 4 discusses the methodology and the various research methods adopted for the implementation of the study, along with the data collection methods and case studies as verification and validation of the process. A detailed justification is given about the selected methodology as the most appropriate for this research. Furthermore, this chapter provides the steps followed to complete the integrated cost management system (ICMS-P) and all the stages involved; from the conceptual design for completing the process, together with the internal mechanism analysis, to achieving the final aim.

Chapter 5 is a comprehensive analysis of how the integrated cost management system was developed and the application of the system. It includes all the internal analysis of the system requirements, the techniques used and the outputs derived. It describes the architecture of the Integrated Cost Management system and the stages of the development. Additionally, the chapter presents the complete application of the system with extended illustrations that provide screen dumps and tables to justify its success, together with analysis of the whole integration process and how this was achieved. Finally, it provides the results and analysis of the internal workings and configuration of the developed system for the context of the study and the guidelines on using the system.

Chapter 6 presents the study cases, with a comprehensive analysis of real data and information used by users' groups and the results and findings of those reported cases. The chapter also addresses the validation of the new system.

Chapter 7 provides a discussion of how the system can be exploited as a powerful tool to support decision making by project and policy executives. The chapter also describes the innovative contribution made by the developed system in the project delivery process.

Chapter 8 summarizes the work and identifies the conclusions, the contribution to the knowledge, the limitations of the developed system and recommendations for its exploitation by industry. It also suggests a guide for future research and the direction in which future work in this field should move.

CHAPTER TWO: MANAGING CONTEMPORARY PROJECTS AND PROJECT COST

2.1 OVERVIEW

The following chapter focuses on the general review of literature related to work in cost management and how cost is managed in contemporary projects.

It initially focuses on the general background and concepts related to the delivery of projects. The function of cost management forms part of the process of the management for the total project, and this is briefly addressed in this chapter. Project conditions and environment have been set in a contemporary environment where complexity increases rapidly and the economic environment becomes more challenging day by day.

The literature investigation continues in this chapter with a review of the traditional approaches in managing costs, describing the main two phases of cost management; cost estimation and the cost control process.

The limitations of existing traditional approaches are also analysed in this chapter. The limitations are divided into their internal mechanism or function, which is not adequate for successfully delivering a project, and as a growth environment, which makes them limited in being updated as cost management approaches.

The literature continues with discussing the process approach in managing project cost. Emphasis is given to the poor performance of existing processes and their flow of information in the cost management stages. Cost planning and cost control processes are also described, with an emphasis on the data and inputs that are used in each stage of the cost management processes. This chapter ends with an investigation of various types of projects that the existing and traditional cost management systems are related to.

2.2 BACKGROUND ON DELIVERING PROJECTS

The management of construction projects requires a knowledge of modern management practice as well as an understanding of the design and construction process. According to the Project Management Body of Knowledge Guide (2001), construction projects have a specific set of objectives and constraints, and project cost management is listed as one of the core areas in which a project manager should be competent (PMI, 2013).

Traditional methods of managing cost have been driven by the design of product and process, rather than serving as criteria for acceptable designs. Cost management has attempted to exert control after budgets have been fixed and to act in the recovery of targets. Very often, the organization which controls the cost is different from the organization which prepares the cost estimates, sometimes using different techniques and/or software. Furthermore, the lack of integration between the inception stage and finishing stage, including mid stages, usually leads to a loss of efficiency, productivity and performance in any traditional cost management system, and that becomes one of the major reasons for projects being completed over budget and delayed.

2.2.1 MANAGING COST OF PROJECTS

Changes in projects affected by a rapidly changing environment drive the costs and decision-making policy. Construction schemes include many people with a range of expertise and, often, with a background other than in construction or civil engineering. Especially in large construction schemes and projects, the risks and complexity factors are high, and project managers have a huge challenge when trying to forecast the overruns and the delays. In this environment, managing the costs in projects is a key role to success, and it often drives decisions.

In a construction project, significant uncertainty exists throughout the project. As Salem et al (2006) argued, weather conditions, soil conditions, owner changes, and the interaction between multiple operations can produce unique circumstances, which could be as critical as the planned activities, and have a significant impact on project cost.

Ustinovičius et al., (2006) argued that every construction project is unique, with unique data and environment, and it experiences a high degree of information uncertainty. All construction projects experience unexpected situations and uncertainties, due to their implementation: and project managers must be ready for this. According to Hendrickson (2008), the uncertainty in undertaking a construction project comes from many sources, and often involves the many participants in the project. Since each participant tries to minimize their own risk, the conflicts among various participants can be detrimental to the project

According to Uher (1996) and Kim (2007), the effective management of risk by contractors is of paramount importance, particularly the management of cost. That happens because, with the increasing complexity of projects, greater constraints are placed by clients on time and cost, periodic economic fluctuations, and the generally risky nature of the construction process.

Failure to recognize and manage potential risks often leads to undesirable results for the project (Hendrickson, 2008). The amount of contingency that the uncertainty generates is based on historical experience, and the expected difficulty of a particular construction project. Socioeconomic factors, organizational relationships and technological problems are the main areas where the risks in construction projects may be classified. According to Doloi et al. (2011), in most construction estimates, there is an allowance for contingencies or unexpected costs occurring during construction, but as Hendrickson (2008) argued, regarding the problem of uncertainty, it is important to recognize that incentives must be provided if any of the participants are expected to take a greater risk.

Design development changes; different site conditions, inflation, communication, general administration changes may variegate the initial estimate (European Commission User's Guide, 1998). These changes and conditions may be included in each cost item or be included in a single category of construction contingency; hence they are quantified and analyzed even if construction has already started. The effective measurement process that the integrated system generates can provide early warning of problems associated with risks, allow time to prevent problems and manage the cost of the contingency effectively.

2.3 TRADITIONAL APPROACHES TO MANAGING PROJECT COST

2.3.1 ASPECTS OF CURRENT COST MANAGEMENT SYSTEMS

Cost is one of the major factors in decision making at all stages of the. In today's environment, where competition is a global phenomenon, profits have been reduced or minimized dramatically; managing project cost plays a dominant role in the whole process and life cycle of the project. Most traditional approaches of managing costs rely on traditional breakdowns, simplified budgets in cost estimation and cost control processes. These procedures follow specific rules and simple parameters based on quantities, types, sizes, and other linear factors. This assumption of simplification of the factors used in traditional approaches of managing costs is questionable in today's environment

Traditional cost management processes such as job order costing, process costing, standard costing and variance analysis, traditional budgeting and cost volume profit (CVP) analysis are no longer adequate in the present environment, one generating uncertainties in companies' operations in delivering projects (Atkinson et al., 2003). Special notice is given to criteria that existing traditional cost management systems serve and the consequences of applying them.

In another study by Membah et al. (2015), it was argued that in most construction projects, cost management involves traditional estimation techniques and cost control procedures, mostly prepared by different people, which often leads to a greater cost of design than estimated. This inconsistency is wasteful and reduces the value of the project.

Companies often hire professionally educated engineers and estimators to manage the cost, and those engineers typically require several years to develop expertise in performing the task. However, Staub et al. (2003) concluded that despite this training, owners and contractors find that there can be a wide range of construction cost estimates by different estimators for the same project, and that the lack of contingency in the current process often leads to overestimating or underestimating construction costs, resulting in lost opportunities or unexpected expenses, respectively.

Lopez (2012) and Ballard (2006) described that traditional methods of managing cost have been driven by the design of product and process, rather than serving as criteria for acceptable designs. Cost management has attempted to exert control after budgets are fixed, by after-the-fact monitoring detection of negative variances, and taking action to recover to targets (Ballard, 2006). Existing traditional cost management systems are mostly based on the same historic principles conducted in the past, according to Kern and Fermoso (2000). Cost information is usually produced too late, and it is too aggregated to be relevant for project management.

The U.S. Government Accountability Office (GAO, 2009) defines a cost estimate as, "the summation of individual cost elements, using established methods and valid data, to estimate the future costs of a program, based on what is known today." The GAO reports that "realistic cost estimating was imperative when making wise decisions in acquiring new systems. According to AACE International's definition, Uppal (1997) mentioned that cost estimation provides the basis for project management, business planning, budget preparation, and cost and schedule control. Included in these costs are assessments and an evaluation of risks and uncertainties.

Cost estimating is the technical process of predicting costs of construction. At its best, it is forecasting and foreseeing a close approximation of the actual construction costs. Its purpose is to postulate the costs required to complete a project in accordance with the contract plans and specifications (Jrade and Alkass, 2001).

Uppal (2001) noted that a cost estimate may be defined as a compilation of all costs of the elements of a project. To a contractor, this is the cost that most likely will be incurred in order to complete the project, as defined in the contract documents, and turn it over to the owner. The contractor's cost is made up of its internal costs as well as those of its subcontractors, suppliers and third parties. The owner's costs are made up of their own costs for administering the project, the cost that the contractor charges the owner for the work performed, and the owner's consultants, engineers and suppliers.

The standard project cost estimating types that are proposed by AACE (Popham, 1996) can be summarized in the following paragraphs.

Order-of-magnitude estimates are made without detailed engineering data. Also known as conceptual or ballpark estimates, variations include the end-product unit method, scale of operations method, ratio or factor method, physical dimensions method, and parametric estimates (Mohammad, 2008; Asmar, 2011). This type of estimate can be used to determine the feasibility of a project quickly or screen several alternate designs. The accuracy range is normally expected to be +50% to -30%.

Budget estimates are made with the preliminary engineering results available and the further defined project scope. These estimates are also known as design-development, semi-detailed, appropriation, or control estimates. This type of estimate is used to determine project feasibility and to establish definitive budgets for the owner, not the project. The expected accuracy range is normally +30% to -15%.

Definitive estimates are prepared from much-defined engineering data according to Popham (1996). Also known as a check, lump-sum, bid, and post-contract change estimates, this category includes estimates ranging from order-of-magnitude to definitive estimates. These estimates are normally accurate within a range of +15% to -5%.

These three types of estimates are used to select the cost estimating technique with the appropriate level of accuracy (Vojinovi, 2000).

Preliminary estimates are usually derived either from historical costs from similar projects (statistical/parametric analysis-quantitative techniques) or from past experience and judgmental/expert analysis (qualitative techniques). Their accuracy is usually very low due to the early stages of a project when the knowledge and details are not well defined. They are very important because they are used for strategic and long- term planning. When planning in advance (a year or longer) the project costs become variable and subject to economic and other fluctuations. It is therefore required that advanced tools be applied in order to produce these forecasts (Garcia, 2014).

Semi-detailed estimates are based on preliminary engineering data and preliminary design specifications. They are used to establish definitive project budgets. Detailed cost estimates are highly accurate because they are based on solid data obtained from very detailed engineering information (design drawings, bill of quantities, and more). They are used for short-term planning, when the costs are more likely to remain stable.

Construction cost estimates may be viewed from different perspectives because of different institutional requirements. Despite the many types of cost estimates used at different stages of a project, cost estimates can best be classified into three major categories according to their functions. A construction cost estimate serves one of these three basic functions: design, bid and control. For establishing the financing of a project, either a design estimate or a bid estimate is used.

To understand cost control analysis, we need to define what we mean by "control." There is a difference between managing cost and controlling cost. Management is the act of handling, directing, or controlling something as King (2000) stated. Therefore, to manage by cost is to succeed in accomplishing a cost objective.

Parker (1993) maintains that Cost Control, however, is a process; i.e., a systematic series of actions directed toward some end. Control can be defined in two ways: to check or verify by comparison with a duplicate register or standard; or to regulate, exercise authority over, direct, or command to take corrective action.

In a project context, control is one of the major tools of project management; this is clearly indicated in most widely accepted definitions of project management, such as those by the Association for Project Management (APM, 2006) and Project Management Institute (PMI, 2008). Project control can be described as the application of processes to measure project performance against the project plan, to enable variances, to be identified and corrected, so that project objectives are achieved (APM, 2013).

This definition of control, when combined with the term cost, gives no guarantee that costs will not rise if cost control is practised. Cost control does not promise the end to poor management, inflation, or over- design. What it does indicate is that there must be a budget baseline against which to compare, so management can spot deviations in enough time to take corrective action. The strong assumption in the term control is that management is willing to exercise authority to take a decision.

2.3.2 IMPROVEMENT POTENTIALS

Managing costs is a subject that, over the years, has become one of increasing concern among academics and professionals. Together with this growth, a significant level of skepticism has arisen in how effective traditional cost management systems are in solving problems associated with delivering projects (Shillinglaw, 1989).

The first set of limitations is that the traditional cost management practices and processes provide inadequate and inaccurate estimates, and therefore they fail in helping managers in decision- making policy.

However, traditional cost management is at a crucial stage in its development, and traditional cost information has become mostly irrelevant, and often dangerous, for managerial purposes (Plossl, 1990).

Furthermore, an increase in regulations and principles over the last two decades have led to a more complicated and more complex application of the traditional cost management approach. Besides that, traditionalists believe that ‘more is better’, and that producing more, irrespective of demand, was rewarded with positive variances and greater apparent profit (Bicheno and Holweg, 2009).

Today, some of the conceptual foundations of this approach are being scrutinized, and project managers are complaining that existing systems fail to meet their needs in the current economic and technological environment (Shillinglaw, 1989). Shillinglaw (1989) also added that it is not clear where this leads to, but what is clear to him is that traditional cost management must change if it is to be a vital force in the future. The information produced by traditional cost management is irrelevant and harmful for projects (Maskell, 2009). According to Bicheno and Holweg (2009), traditional cost management systems were essentially backward; only reporting on past performance, but giving few real pointers how to improve in the future, and are not able to reflect accurately the improvements made over the last few decades.

Looking closely at cost management in the construction industry, it is reported that in the case of cost estimating, the information produced has the additional drawback that it is only remotely related to the way costs are incurred, according to Koskela (2000). Most cost methods that have been adopted in projects are strongly based on standard cost methods, and tend to associate each cost item to a finished element; for example walls (m2), reinforced concrete (m3), windows (units), asphalt (tn), earthworks (m3) and more, obtained from design drawings. This makes it difficult to examine accurately the effect of design changes in construction cost.

Moreover, although time is a factor of major importance in construction costs, traditional cost management methods do not offer any reliable guidance for assessing the impact of cost on a project's life cycle (Kaka and Price, 1991; Turner, 1993; Navon, 1995).

Kim (2002) suggests that cost management approaches and systems should involve a set of processes required to ensure that a construction project is completed within the approved budget, including cost estimation, cost control and cost projection. This argument is supported by Koskela (2000), enabling the result of how difficult is, to examine accurately the effect of design changes or other parameters in construction cost.

This lack of information transfer in all the stages of a project, traditional methods, supports the need to manage all the stages in an integrated way. This hypothesis has also been proposed by Navon (1995), who posited that the proper consideration of the interaction between cost and time in construction projects depends on the integration of cost management processes.

Therefore, cost management systems and processes must be dynamic, proactive and able to support different decision-making processes to protect the project and the business itself from the harmful effects of uncertainty. Their main objective should be to generate information to support decision making, mainly concerned with cost reduction, value improvement and cost management.

Most published literature relating to estimation, particularly textbooks, concentrates on the principle and process involved in its function. This process has suffered the shortcomings that could be expected given the extreme competition that is involved in construction bidding, and the limited understanding of the underlying drivers of construction cost performance. Using these techniques on projects requires an investment of time and money (Griffith, 2006).

Traditional cost management approaches are limited to provide adequate cost management solutions in the complex scenery of contemporary projects. Their limitation is due to the following factors: they require many initial assumptions which are contrary to the reality of delivering any given project, providing thus various cost management models which fail due to the use of misleading parameters; they are not capable of capturing the inherent nonlinear behavior of project data (Vojinovic et al., 2000). Vojinovic et al. (2000) also argued that in reality most of the problems are nonlinear, and therefore applying traditional cost management techniques, which basically follow a linear approach, would consequently become misleading and dangerous.

Traditional cost estimating approaches can be used both for linear and nonlinear environments. Their limitations that finally lead in failure to provide adequate results in managing costs in projects is based on initial assumptions that can then be misleading throughout the whole project delivery, resulting in failure caused by the incorrect establishment of model parameters and a failure to analyze the non-linear nature of project data (Kaskela, 2000; Hanid, 2011). As most of the real projects and their problems are nonlinear, traditional approaches are inadequate for solving problems and providing decision making policy for managers.

To summarise, the traditional cost management approaches have highlighted the need to move to a new approach that meets the new challenges in construction industry regarding project delivery and implementation. According to Popescu (2003) construction cost estimating is generally more an organizational problem than an industry problem. Integration in cost management and using cost management as a core subject in project processes is the new approach that has yet to be extensively researched.

2.4 PROCESS APPROACH TO MANAGING PROJECT COST

2.4.1 PROJECT COST MANAGEMENT PROCESSES

Horngren (1990) defines a cost management system as a framework for project cost information. The system consists of a set of principles, methods and tools whose main objectives are to estimate costs and to generate information to support different managerial decisions during the distinct phases of the project. Cost management systems must be dynamic, proactive and able to support different decision making processes, as well as protect the business from the harmful effects of uncertainty. According to Kim (2002), particularly in the construction industry, cost management systems must include the processes required to ensure that the project is completed within the approved budget. These processes include integration between cost estimating, cost control and cost projection to meet the project targets. The integration systems proposed will be a complete managerial process, which aims to generate information to support decision making and to stimulate cost reduction, value improvement and continuous improvement in the organization. Kern and Formosso (2000) noted that cost management systems are understood as being composed of two main processes - the cost estimating process and cost control process - in an integrated environment.

Cost management is a major discipline in delivering construction projects of different sizes and complexity. Traditional cost control processes are also criticized because they simply identify variances by monitoring actual performance against cost estimates. To address these inherent weaknesses in the current practice of cost management, a framework for an integrated system has been proposed which aims to cover the gaps of traditional methodology by integrating the stages in a project's complete life cycle.

Cost management consists of two main elements, cost estimation and cost control. Project cost estimating involves developing an approximation of the costs of the resources needed to complete project objectives (Vojinovic et al., 2000). On the other hand, cost control is the continuing process to keep the project within cost objectives and satisfy client's needs

In general, a construction cost estimate is prepared to identify the costs required to execute a project in accordance with its plans and specifications (Jrade and Alkass, 2002). Throughout a construction project life cycle, many cost estimates must be prepared or revised, depending on the information and engineering drawings that are available at any time. Cost Estimation is also a process of developing a well-defined relationship between a cost object and its cost driver for predicting the cost (Ballard, 2006).

2.4.2 COST ESTIMATING PROCESS

The objective of a cost estimating process is to estimate the cost of a project. This requires a thorough understanding of the design, contracts, procurements and construction to properly model the sequences and manage the resources of the estimation process. In construction, the cost estimating process usually starts by producing a budget, normally at the very early stages of the project. It is a very important cost document which is constant throughout the project's life cycle and is often part of the project main contract (Soetanto, 2006). This initial estimate also serves as a reference for cost planning and control.

As project cost estimating is a very complex task due to the inherent uncertainty and variability of construction, the cost control process must provide feedback on the cost estimating process to improve the quality of information available in the cost database that will be used for other projects in the future (Thorpe and McCaffer, 1992). The purpose of an estimate is to provide the client and design team with as precise an estimate of final costs as possible so that the project can be accomplished within the client's budget.

2.4.3 METHODS OF COST ESTIMATION

Cost estimating is one of the most important steps in cost management, and generally the project management itself. It provides the baseline of the project cost at many different stages and over the whole life cycle of the project. At any given stage, the cost estimation always represents the prediction on the current available data. All existing estimations are described one by one in various stages of project delivery.

PMI (2008) defines cost estimation approaches and the way they function in managing cost; empirical, bottom up, top down and other approaches have been here presented.

Cost estimation is performed using one or a combination of the following:

- Production function. In microeconomics, the relationship between the output of a process and the necessary resources is referred to as the production function. In construction, the production function may be expressed by the relationship between the volume of construction and a factor of production, such as labour or capital. A production function relates the amount or the volume of output to the various inputs of labour, material, and equipment. For example, the amount of output Q may be derived as a function of various input factors x1, x2, …xn by means of mathematical and statistical methods. Thus, for a specific level of output, we may attempt to find a set of values for the input factors so as to minimize the production cost (Caputo and Pellagage, 2015).
- Empirical cost inference. An empirical estimation of cost functions requires statistical techniques which relate the cost of constructing or operating a facility to a number of important characteristics or attributes of a system. The role of statistical inference is to estimate the best parameter values or constants in an assumed cost function (De Souza et al., 2015; Migliaccio et al., 2015).
- Unit costs for a bill of quantities. A unit cost is assigned to each of the facility components or tasks as represented by the bill of quantities. The total cost is the summation of the products of the quantities multiplied by the corresponding unit costs. The unit cost method is straightforward in principle but quite laborious in the application. The initial step is to break down or disaggregate a process into several tasks. Collectively, these tasks must be completed for the construction of a facility. Once these tasks are defined and quantities representing these tasks are assessed, a unit cost is assigned to each and then the total cost is determined by summing the costs incurred in each task (Chou, 2011).
- Allocation of joint costs. Allocations of cost from existing accounts may be used to develop a cost function of an operation. The basic idea in this method is that

each expenditure item can be assigned to a part of the operation. Ideally, the allocation of joint costs should be causally related to the category of basic costs in the allocation process. In many instances, however, a causal relationship between the allocation factor and the cost item cannot be identified or may not exist. For example, in construction projects, the accounts for basic costs may be classified as 1) Labor, 2) Material, 3) Construction Equipment, 4) Construction Supervision, 5) Subcontractors and 6) General Office Overhead expenses. These basic costs may then be allocated proportionally to various tasks which are subdivisions of a project (Chan, 2011).

All the above estimates provide solutions for individual project elements towards a project total. The pieces can vary in size and number from a few large chunks of a project with known costs to hundreds or thousands of discrete tasks or individual work packages formed in a Work Breakdown Structure (W.B.S.).

Bottom up estimates are often prepared by contractors to support their proposal bid process. This involves a detailed WBS and pricing out each work package making up the project. This approach may be laborious and time consuming, but it can result in a fairly accurate estimate if the work content is well understood (van Vuuren et al., 2009; Chen et al., 2010).

Top-Down estimates use rule of thumb, parametric models, analogies, or cost estimating relationships. The final items, based on historical experience, can provide data such as the cost to develop a source line of software or the cost per square meter for a building project, for example (van Vuuren et al., 2009; Chen et al., 2010).

Sometimes project goals are a force-fit based on the amount of money available in the budget. This will require the project manager to initiate a cost estimate to find out if the project is feasible. Adjustments in scope may be needed so the project can survive.

Design-to-Cost is a process where the cost goals for development, acquisition, or operations and maintenance are used as design parameters, along with technical performance, in the system’s design trade-off process. In cases where the absolute value of a dollar threshold needs to be contained, the project definition, conceptual design, and development can address performance trade-offs to fit the project within a predetermined cost envelope (Chapman, 1997).

Cost as an independent variable is an approach which starts with a fixed budget and works backwards, through an iterative process of prioritizing and selecting requirements, to arrive at a project scope achievable within budget constraints (Afetornu, 2011).

Costs can usually be estimated with acceptable accuracy by using relevant historical data, a well-constructed and documented estimating methodology, and a good understanding of the work content to be performed. This approach involves putting as much detail into understanding the tasks as possible and generating assumptions with whatever shreds of knowledge may be available (McCaffer and Baldwin, 1984; McCaffer et al., 1984).

If equipment is to be acquired, a recent analogous vendor quote will be helpful. Experience shows, however, that analogous cost data are often not analogous. For this reason, the cost estimator will want to determine: whether the configurations are similar; any field of changes; installation; and if their costs are not included in estimation. These same principles apply to using costs from similar projects or service contracts. It is sometimes useful to take available cost data and shape it using size and complexity factors to estimate costs for analogous, yet distinctly different, project efforts.

If the estimation for the number of source lines of specific software is uncertain, it is preferable to add an uncertainty factor to the estimate. This factor has, at the initial stage, a range of 15% to 35% (Chapman, 1997). It may be prudent to add a contingency factor to account for expected changes, or to allocate management reserves to deal with later eventualities.

Cost estimates are developed for different reasons, and the purpose of the estimate usually imparts a bias to the numbers. When we evaluate the accuracy of an estimate, it is necessary to know the source of the estimate and the purpose for which it was derived.

From the Project Manager's perspective, it is important to know if the cost estimates are about to lead to cost overrun, and if they hide any underestimate or overestimate which will need to be managed within the construction and control period.

It is well understood that good results in cost estimates require a supportive environment in the organization. The only way to support this is to create detailed Work Breakdown Structure categories, and then collect the actual costs in a historical cost database. A cost database for software, for instance, could be used to collect data related to cost per line or per unique ID code, software algorithms wherever these are used, costs for function points, or cost data from bottom-up functional descriptions and tasks.

A well-defined cost estimate is also unmanageable and difficult to alter with corrective actions, due to the many changes taking place throughout the implementation of the project, unless a good record of documents is kept to support these changes and provide information for corrective actions (McCaffer et al., 1983).

Uppal (2001), in AACE transactions, identifies estimating as an approximation procedure that provides answers with significantly less than 100 percent probability of being correct or even close. Thus, understanding the accuracy limitations of an estimate and its potential variation is extremely important to the user or the estimator or even the project manager.

Uppal (2001) also gives also the definition of a cost estimate as a compilation of all costs of the elements of a project or effort included within an agreed-upon scope.

In real projects, we may find another distinction in cost estimates. The contractor estimates and the owner estimates. For contractors, the cost is referred to the costs that are incurred to complete the project and turn it over to the owner. On the other hand, the owner's cost is the summation of contractor's cost plus the administrator costs of his own business, plus any consultants, engineers and suppliers that will be used (McCaffer et al., 1983).

Based on this approach, we may divide the cost estimating into basic elements which could be designated as estimate types, the direct and indirect costs and the elements of costs for labour, materials and equipment.

No matter the approach each company chooses to accept, the cost estimates are affected by various factors which are called unpredictable or unforeseen, such as weather, time delays, changing locations, changing capacity, cost of material based on time (oil price) and field of changes in design process even during the control stage. The estimator or the user must be aware and predict those changes based on experience and historical data records. Construction cost estimating is generally more of an organization problem than an industry problem (Baldwin, 2014).

Monsey (1997) referred to cost as the amount paid or to be paid for a purchase. To make an estimate is to make a judgment as to the likely or appropriate cost. Based on Monsey, a question must be asked about estimates. What is cost estimating and why it is done? Essentially, it is the outcome of translating complex ideas that have been put down on paper or electronically. These ideas are based on a combination of labor, material, equipment and other costs combined with other factors. Hence, the numbers lead to a final monetary value.

2.4.4 COST PLANNING AND COST CONTROL PROCESSES

After costs have been estimated, the financial performance must be planned and controlled during the planning and procuring stage by means of a cycle composed of two sub-processes; cost planning and cost control.

Cost planning involves refining the initial cost estimate and generating a project cash flow based on additional information that is generated throughout the project, such as a schedule of payments for the main material suppliers and subcontractors, which should be based on production plans. This sub-process may support decision making in an efficient way, to increase the likelihood of achieving project plans and meeting the project's objectives (Thorpe and McCaffer, 1992).

In addition to cost estimating, the process relies heavily on feedback from the cost control process. Plans must be changed whenever necessary, and situations that need special attention must be highlighted.

The aim of cost control as a sub-process is to monitor actual cost performance and identify improvement opportunities, which must be dealt with by employing corrective actions. It should not be limited to comparing current and estimated performance, but also focused on value generation (Parker, 2014). Control is conceived as monitoring each project or activity against its budgets projections (Howell, 1999).

During the execution of a project, procedures for project control become indispensable tools to managers and other project participants in project delivery. These processes give the managers a picture of the project in terms of progress and problems associated with the project itself. Project control procedures are primarily intended to identify deviations from the project plan rather than to suggest possible areas of cost savings, and this is an important limitation that the traditional cost management systems offer.

For cost control, the construction plan and the budget estimates can provide the baseline for the subsequent project monitoring and control. Therefore, progress can be compared with the progress schedule and controlled through monitoring the activities of the project or the project as a whole process (McCaffer, 1984).

All cost elements can be compared in the control stage, and this procedure provides information in terms of labor productivity, material usage, and sub-contractors' efficiency control. The control process involves a package of reports and information in specific forms usually through systems and software.

2.5 CONTRACTS TYPES IN PROJECT COST MANAGEMENT PROCESS

In this section, different types of contracts and projects have been analyzed to define the importance of the integration in a wider spectrum of construction industry projects, and a wide range of contracts.

2.5.1 CONTRACTS

In the UK construction industry, the rules and the variables of each project are considered through the various types of construction contracts. The types of contracts define the design and construction method of each project, together with the methods of payment of each participant of the contract (Langford et al., 2003).

This research explores the most common types of contracts and sets the variables showing how each contract will affect the integrated cost estimation and cost control system.

To succeed in having a complete literature review, all current contract types related to cost management should be reviewed because contracts affect the existing cost management approaches (Chen et al., 2016).

The PMI (2008) defines the following types of projects which are considered in this research.

- ***Lump Sum*** *(Firm Fixed Price)* ***Contract***. Lump sum contracts are used mainly for assignments in which the content and the duration of the services and the required output of the consultants are clearly defined. They are widely used for simple planning and feasibility studies, environmental studies, detailed design of standard or common structures, preparation of data processing systems, and so forth. Payments are linked to outputs (deliverables), such as reports, drawings, bills of quantities, bidding documents, and software programs. Lump sum contracts are easy to administer because payments are due on clearly specified outputs (Qiu and Wang, 2011). Lump Sum Contracts allow integration in cost management processes but special focus must be given in the early stages when the cost allocation is set up. That stage could be the design or preconstruction stage, where all variables of the project need to clarified and connected with the cost breakdown of the lump sum.

- ***Time-Based Contract**.* This type of contract is appropriate when it is difficult to define the scope and the length of services, either because the services are related to activities by others for which the completion period may vary, or because the input of the consultants attaining the objectives of the assignment is difficult to assess. This type of contract is widely used for complex studies, supervision of construction, advisory services, and most training assignments. Payments are based on agreed hourly, daily, weekly, or monthly rates for staff (who are normally named in the contract) and on reimbursable items using actual expenses and/or agreed unit prices. The rates for staff include salary, social costs, overheads, fees (or profit), and, where appropriate, special allowances. This type of contract includes a maximum amount of total payments to be made to the participants. This ceiling amount should include a contingency allowance for unforeseen work and duration, and provision for price adjustments, where appropriate. Time-based contracts need to be closely monitored and administered by the client to ensure that the assignment is progressing satisfactorily, and payments claimed by the consultants are appropriate. (Lenferink et al., 2013). This time-based contract is useful in integration processes because it uses time rate variables. Time rate variables are key variables in the development of the new integrated cost management system.
- ***Retainer and/or Contingency Fee Contract**.* Retainer and contingency fee contracts are widely used when consultants (banks or financial firms) are preparing companies for sales or mergers, notably in privatization operations. The remuneration of the client or the contractor includes a retainer and a success fee, the latter being normally expressed as a percentage of the sale price of the assets (Chen et al., 2016; Akbiyikli, 2016).

- ***Percentage Contract***. These contracts are commonly used for architectural services. They may be also used for procurement and inspection agents. Percentage contracts directly relate the fees paid to the Consultant to the estimated or actual project construction cost, or the cost of the goods procured or inspected. The contracts are negotiated on the basis of market norms for the services and/or estimated staff-month costs for the services, or competitively bid. It should be borne in mind that in the case of architectural or engineering services, percentage contracts implicitly lack incentive for economic design and are hence discouraged (Hurk, 2016). Therefore, the use of such a contract for architectural services is recommended only if it is based on a fixed target cost and covers precisely defined services.
- ***Indefinite Delivery Contract*** (Price Agreement). These contracts are used when borrowers need to have "on call" specialized services to provide advice on an activity, the extent and timing of which cannot be defined in advance. These are commonly used to retain "advisers", normally for a period of a year or more, for: implementation of complex projects (for example, dam panel), expert adjudicators for dispute resolution panels, institutional reforms, procurement advice, technical troubleshooting, and so forth. The borrower and the firm agree on the unit rates to be paid for the experts, and payments are made based on the time used (Stanford et al., 2016).

Instead of inviting competitive bidding, private owners often choose to award construction contracts with one or more selected contractors. A major reason for using negotiated contracts is the flexibility of this type of pricing arrangement, particularly for projects of a large size and great complexity or for projects which substantially duplicate previous facilities sponsored by the owner. An owner may value the expertise and integrity of a contractor who has a good reputation or has worked successfully for the owner in the past. If it becomes necessary to meet a deadline for completion of the project, the construction of a project may proceed without waiting for the completion of the detailed plans and specifications with a contractor that the owner can trust. However, the owner's staff must be highly knowledgeable and competent in evaluating contractor proposals and monitoring subsequent performance. Such negotiated contracts rely on reimbursement of direct project cost plus the contractor's fee as determined by one of the following methods:

1. Cost plus fixed percentage
2. Cost plus fixed fee
3. Cost plus variable fee
4. Target estimate
5. Guaranteed maximum price or cost (Berends et al., 2004)

The fixed percentage or fixed fee is determined at the outset of the project, while a variable fee and target estimates are used as an incentive to reduce costs by sharing any cost savings.

2.5.2 TYPES OF CONSTRUCTION PROJECTS

A wider spectrum of types of projects is being described in order to define how these types of projects are affected by applying the traditional way of managing projects.

The various types of projects can be quite different. For research purposes, the broad spectrum of constructed facilities may be classified into four major categories, each with its own characteristics as defined in the PMBOOK Guide (PMBOOK Guide, 2008).

- Residential housing construction
- Institutional and commercial building construction
- Specialized industrial construction
- Infrastructure and heavy construction

The basic idea when this topic was undertaken was to prepare this system for as many different types, if not the whole spectrum of projects in construction industry. To accomplish this aim, it is necessary to design more than one cost estimation and control system, but following the same principles. The current analysis excludes the Specialized Industrial Construction projects due to the many levels of detailed analysis required. Projects like oil refineries, chemical plants, power plants and nuclear plants, need a more specialized cost management system, and each project is defined as unique; therefore, they cannot be categorized as other projects, under a specific cost management system. The other three main categories have many similarities and can be used in a common cost management system.

- **Residential Housing Construction**

Residential housing construction includes single-family houses, multi-family dwellings, and high-rise apartments. During the development and construction of such projects, the developers who are familiar with the construction industry usually serve as surrogate owners and take charge, making necessary contractual agreements for design and construction, and arranging the financing and sale of the completed structures. Residential housing designs are usually performed by architects and engineers, and the construction executed by builders who hire subcontractors for the structural, mechanical, electrical and other speciality work. An exception to this pattern is for single-family houses which may be designed by the builders as well.

The residential housing market is heavily affected by general economic conditions, tax laws, and the monetary and fiscal policies of the government. Often, a slight increase in total demand will cause a substantial investment in construction, since many housing projects can be started at different locations by different individuals and developers at the same time. Because of the relative ease of entry, at least at the lower end of the market, many new builders are attracted to residential housing construction. Hence, this market is highly competitive, with potentially high risks as well as high rewards (Kim et al., 2012).

- **Institutional and Commercial Building Construction**

Institutional and commercial building construction encompasses a great variety of project types and sizes, such as schools and universities, medical clinics and hospitals, recreational facilities and sports stadiums, retail chain stores and large shopping centres, warehouses and light manufacturing plants, and skyscrapers for offices and hotels. The owners of such buildings may or may not be familiar with construction industry practices, but they usually can select competent professional consultants or project management companies or specialized contractors and arrange the financing of the constructed facilities themselves. Specialty architects and engineers are often engaged in designing a specific type of building, while the builders or general contractors undertaking such projects may also be specialized in only that type of building.

Because of the higher costs and greater sophistication of institutional and commercial buildings in comparison with residential housing, this market segment is shared by fewer competitors. Since the construction of some of these buildings is a long process which, once started, will take some time to proceed until completion, the demand is less sensitive to general economic conditions than that for speculative housing. Consequently, the owners may confront an oligopoly of general contractors who compete in the same market. In an oligopoly situation, only a limited number of competitors exist, and a firm's price for services may be based in part on its competitive strategies in the local market.

- **Infrastructure and Heavy Construction**

Infrastructure and heavy construction includes projects such as motorways, mass transit systems, tunnels and underground works, bridges, drainage pipe projects and sewerage treatment plants. Sometime in big schemes we may find a combination of the above subcategories under a unified contract as a big project. For example, an excessive budget motorway project includes bridges, tunnels, sewerage works, and drainage pipeline systems (Paraskevopoulou, 2013). Most of these projects are publicly owned, and therefore financed either through bonds or taxation. Nowadays we usually find another form of project especially in big schemes, named a PPP project. This Private Public Partnership is joint funded from the private and public sector under a concessionaire agreement and contract, and their main advantage is to complete the project quickly, under specific regulations and standards. In some markets, these are called fast track projects.

The infrastructure projects are characterized by a high degree of mechanization. The engineers and builders engaged in infrastructure construction are usually highly specialized since this segment of the market requires different types of skills. However, as Hollar (2013) argued, demands for different segments of infrastructure and heavy construction may shift with saturation in some segments. For example, as the available highway construction projects are declining, some heavy construction contractors quickly move their workforce and equipment into another field where jobs are available.

2.6 LITERATURE REVIEW ASPECTS

Literature shed light on, the complexity within the modern construction environment of managing cost in projects. The risk has been increased with the complexity, hence the uncertainty of managing cost has been increased.

There are clear limitations in today's' approaches which significantly affect the managing procedure in a project. These limitations lead to greater cost than was estimated in the programming and design stage. Traditional methods have been driven by project design rather than being a part of the whole procedure in managing and delivering projects. The uncertainties arising from this highlight the fact that cost information is produced too late to be helpful and to support any decision making for the project delivery.

The investigation of various traditional approaches of estimation illuminates the problem of uncertainties throughout the life cycle of the project. Therefore, scepticism is today found to be growing because the risks and uncertainties are growing. Solving those problems requires such systems that are dynamic and proactive throughout the project life cycle.

During the various project stages, too many estimates are prepared hoping to cover the project needs. Investigation and analysis of various estimates have highlighted the problem and the weaknesses in trying to establish an adequate way of managing costs, hence managing the projects.

Each method has its own characteristics that represent only one small part of the whole procedure of managing the project in all stages. The control stage is the final action of the process, with limited productivity and limited information, to provide solutions and suggestions to put the project back on track if needed. The lack of information in the estimation stages is breaking the chain of cost management as a complete procedure.

2.7 SUMMARY

Chapter Two is the first chapter of two that analyze the literature regarding the management of construction cost. The review of the literature has resulted in the identification of the dominant drawbacks that are associated with how traditional cost estimates are established, as well as the limitations of other processes involved in the estimating, planning and control stages.

These drawbacks focus on inadequate and inaccurate estimates, which lead to failure in project delivery and failure to support managers in decision making policy. Assumptions, and their simplicity, do not reflect today's complexity in projects; therefore, traditional approaches cannot provide adequate solutions.

From the literature it was found that traditional cost management approaches rely on assumptions, and cannot meet the nonlinear behavior of the projects. This situation leads to misleading data and a failure to successfully deliver projects.

Another important highlighted drawback is the functional effect of traditional cost management. The most important drawback found here in the literature review is that traditional methods of managing costs have been driven by the design of a product and process, rather than serving as criteria for acceptable designs. That means that cost management has attempted to exert control after budgets are fixed, leading to loss of efficiency, productivity and performance. This limitation of current cost management techniques has led us to an understanding of the complexity of contemporary project schemes and how important cost management is in a project's implementation. Even if the current practices in cost management appear to be incomplete as systems, they have potential if they were to be used within an integrated scheme, with the positive variables and factors working as an integrated process.

The comprehensive analysis of types of contracts and procurement methods and strategies, and the wide spectrum of construction projects, supports the hypothesis of complexity existing in managing projects, hence the need to move towards integration of the processes under a cost management system that covers all the gaps and limitations found on traditional cost management approaches. The common practices that this work investigates are the current cost management processes. The new proposed cost management system uses these techniques and their strengths to bring about the integration of those traditional systems. The literature review of cost management approaches has led us to investigate all current traditional cost management techniques. These techniques are fully described in all stages of the project, with emphasis on their strengths and weaknesses and how those systems could be part of the whole new integrated cost management system. Cost management methods, tools and aspects are analyzed in the following chapter, providing crucial information and an understanding of the processes of cost management as a core feature of project delivery.

CHAPTER THREE: COST MANAGEMENT IN PROJECT DELIVERY

3.1 OVERVIEW

This chapter focuses on cost management methods that are employed in project delivery. These methods are part of cost management systems and their main purposes are to facilitate the preparation of the estimates and produce essential control information.

The chapter starts with the origin of cost estimation and cost control methods. Analogous estimating is described and compared with resource cost rates estimation and bottom up estimation. Additionally, the ABC method and parametric estimation are described separately.

Continuing the literature review in this chapter, important cost management aspects are analyzed, such as the importance of preparing many cost estimates throughout the project life cycle. The way that cost management aspects were involved with manufacturing processes is also described. Finally, improvements in aspects of current cost management practice have been described. Note, there is a clear distinction here between the construction industry and manufacturing industry.

The review also addresses the dominant factors that often serve as constraints in the management of project cost. It highlights the connection between those constraints and the overall performance of project cost management. It also focuses on the key principles that underpin the use of time and the cost information to support the production of cost estimates.

Finally, the chapter clarifies the drawbacks of traditional cost management systems and how these drawbacks can be overcome and improved through the adoption of a system-wide integrated cost management solution.

3.2 GENERAL CONTEXT

The cost management system is regarded as a framework for project cost information. Such systems consist of a set of principles, methods and tools whose main objectives are to estimate costs and to generate information to support different managerial decisions during the distinct phases of a project. Cost management systems must be dynamic, proactive and able to support different decision making processes, as well as to protect the business from the harmful effects of uncertainty. According to Kim (2002), particularly in the construction industry, cost management systems must include the processes required to ensure that the project is completed within the approved budget.

Special notice and analysis is provided in this chapter to the ABC estimation methods as one of the most widely used by organizations and construction companies even today. Together with the ABC method of estimation, parametric estimation, which is also widely used by both contractors and clients, is also analysed.

To realize the need of cost management, the origin of cost estimation and cost management has been investigated in the literature. Historical perspectives go back to the 1950s, where the PERT analysis and CPM analysis were first employed. Special attention was also given to the need to improve cost management and how this would lead to an increase in the value of a client's investment.

Attempts to improve the cost management and whether enough effort was put into this improvement are discussed.

How companies managed to adopt these newly developed methods or not, and if these methods were able to solve the problems in project delivery is discussed. The directions where the research of cost management should move from now, and what factors the improvement of cost management should rely on, as presented in the literature, are also highlighted.

3.3 HISTORICAL PERSPECTIVES ON COST MANAGEMENT

Modern project cost management methods have been used for almost fifty years. The then innovative Critical Path Method (CPM) for work development, and the Performance Evaluation and Review Technique (PERT) were first used in the 1950s (Griffith, 2006).

Since then, the construction industry has spent time and money trying to discover new methods and new techniques to solve its own problems. Although CPM and PERT basic principles are still used today and have not changed, significant and important changes have been made in the succeeding years since these two techniques were used for the first time.

The literature identifies a considerable amount of today's knowledge focused on project cost management, both in estimating and control methodology (Simmons, 2002; Haga and Marold, 2004). The AACE International and other organizations very often publish articles and analysis, as well as announcing new estimation and control techniques. As Griffith (2006) describes, the developmental research is ongoing; however, empirical research demonstrating the value of good scheduling practices and methods is minimal. Most of published work in the cost management area is based on case studies and expert knowledge. A limited number of projects have led to false conclusions concerning those methods. The construction industry has spent an enormous amount of time and money on training and software systems related to project estimation and cost control techniques to such an extent that a whole branch in the construction economy now offers this kind of services in projects. Companies pay a lot to employ these services to involve them in their dynamic project force.

It is widely known that over the past 50 years of development, research and improvement in those systems, a considerable number of large and small investments have been made in method development and research in order to support the industrial scheme as we know it today, according to Moby et al. (2002). It may be worth asking if these investments have paid off or not, according to Griffith

(2006). As the AACE mentioned, there is publicly available data that supports the policy of investing in project- scheduling tools and methods. Since empirical research demonstrates minimal value of good practice, according to Griffith (2006), it can be argued that an investment of time and money is needed in each project in order to apply the research and enjoy industry growth.

Most recent work and research in the cost management area is based on expert knowledge, gathered from a large number of companies. Some of these companies identify and measure the practices and their effects on project outcomes and results. There is a wide variety and choice from the many methods developed over the last fifty years of improvement in the construction industry. The construction industry private sector has the greatest freedom to use and project delivery methods (Molenaar, 2004). They have a considerable range of traditional methods to employ, or they can choose one of the most recent ones that focuses on more efficient cost management (Filip et al., 2016).

On the other hand, the public sector faces serious constraint that allows only the minimum flexibility in managing cost in projects. This constraint is mainly based on two discrete stages; the design stage and the construction stage (Matto and Sippola, 2016).

Cost management is a technical process predicting and controlling costs of construction (CIOB, 1983). Law (1994) has documented a general procedure for contractor cost estimating. However, he believed that in practice, contractors devise their own methods of cost estimating and bidding. Hegazy and Moselhi (1995) have mentioned that very often these methods are inaccurate and not well structured and are based mostly on contractors’ experience (Akintoye and Fitzgerald, 2000).

The cost management function provides a basis for the contractor to submit, for example, a tender sum for the project. Skitmore and Wilcock (1994) have contested that the assumption that tender prices are based on estimates of future expenditure is questionable. Evidence has shown that estimators try to avoid the real problems (uncertainties) by presenting socially acceptable forecasts (Skitmore and Wilcock, 1994).

Cost management methods have been developed for preparing estimates and control procedures of various types of projects and for various purposes (Daschbach and Apgar, 1988). Law (1994) documents a systematic procedure, format and methods involved in UK contractors estimating in relation to labor, plant, material, subcontractors, overhead and profit. Alternatively, the components of the cost estimates can be grouped into either direct and indirect costs, or variable and fixed costs (Carr, 1989).

Ntuen and Mallik (1987) have identified techniques or modeling tools for cost estimating which are classified into four groups:

- Experienced based (algorithms, expert)
- Simulation (heuristics, expert, decision rules)
- Parametric (regression, statistical)
- Discrete state (Linear programming, optimization, network, PERT, CPM).

The construction literature on cost management has produced a theoretical basis for the principles involved in process of managing costs in the delivery of projects. Until recently, very few were known about the current state of cost management practice. However, much progress has been made in research and the teaching of cost management during the past two decades. Although changes are taking place, construction firms continue to rely on outmoded cost management systems. After all the shortcomings of traditional cost management being reported, Spicer (1992) has claimed that there has been a remarkable resurgence of interest in both the practice and theory of cost management in recent years. The main reason for this resurgence is reaction to the considerable changes which have taken place in the business environment as global competition has increased the rhythm of technological change and the economic deregulation of industry in various countries (Jiang et al., 2011).

3.4 COST MANAGEMENT METHODS AND TOOLS

According to its definition, project cost estimating involves developing an approximation (estimate) of the costs of the resources needed to complete project objectives. Projects may vary from a feasibility study, through modification of existing assets, to complete design, procurement, and construction of a large complex. Whatever the project is, the type of its estimate may differ. Estimate is dependent upon the available information, time demands, purpose of the estimate, and technique. There are many types of estimates prepared by various authors, companies, professionals, industrial organizations and government agencies according to Vojinovic et al. (2000).

The production of estimates based on the above types, serves one of the three basic functions; design, bid and control. These estimate products are also analyzed and explained as a factor in the project delivery process.

Some types of cost estimating techniques that have been used for years include the following:

- Analogous Estimation
- Resource Cost Rates Estimation and
- Bottom Up Estimation

These techniques have specific characteristics and have a common use in estimating projects. The analysis below identifies the structure of each technique which later will be used to build the structure of the integrated system.

Analogous estimation uses estimates from a closed project to determine the estimates for a new project. The accuracy of this type of estimation depends on similarities between two or more projects.

Resources are required in every project. In resource cost type estimation, the total costs for the resources on the specific project are determined by applying resource cost rates to the estimated activity resources.

Bottom up estimation technique provides a total cost by preparing individual estimates based on the WBS of the project. This is the most commonly found estimation technique applied in projects today because of its high level of accuracy. The main disadvantage is the effort required, which increases together with increasing levels and details in the WBS analysis.

As described, various cost estimation methods are used today. These are considered traditional estimation methods, and include the parametric, analogous and bottom up methods. When choosing a methodology, the company or the manager may always consider that cost estimating is a forecast, a projection of future costs based on a logical extrapolation of available historical data. The method or the type of cost estimating method used today depends on the adequacy of the project definition, the level of detail required, the available data and time constraints (Long, 2000).

Section 7.2.2 of the PMI (2008), includes discussion of four types of estimation techniques: analogous estimating, parametric modeling, bottom-up estimating and computerized tools, and other cost-estimating methods. The broad area descriptions of estimating tools are silent on the methods used by accountants or others to determine cost. The PMI (2008) can be expanded to include a discussion of traditional cost accounting techniques and a discussion of ABC.

Analogous estimating, also called top-down estimating, uses the actual cost of previous or similar projects as the basis for estimating the cost of the current project. This method is less costly than other techniques, but it also is not as accurate as other techniques. This method is most reliable when the project is similar to one that has been completed in the past, and the individuals involved in the project have the expertise needed to make the estimates.

Another method of estimation that is widely used is parametric cost estimating which, according to Bajaj et al. (2002), uses cost estimation relationships and mathematical algorithms to establish final estimates. After almost two decades, the necessity to reduce the inaccuracy of bid costs and reduce the period preparing the estimates has led to the parametric cost estimating method.

Parametric modeling involves the use of project characteristics in a mathematical model to predict project cost. As Long (2000) argued, the "parametric" method of estimating involves collecting relevant historical data, usually at an aggregated level of detail, and relating it to the product to be estimated through the use of mathematical techniques. At the heart of the parametric estimating methodology are cost estimating relationships (C.E.Rs.). A C.E.R. relates cost as the dependent variable to one or more independent variables (Long, 2000).

This method is considered fairly accurate when the historical information used to develop the model is accurate. The parametric approach to cost estimation is a procedure involving the use of a constant parameters as a reference (Melin 1994; Chou, 2011).

The parameters used in this model are quantifiable. The model can be adjusted based on the scale of the project. However, there are a number of programs available that generate a cost estimate from minimal details. Parametric Estimation structures the detailed line items of completed projects into smaller groupings, with a relationship to known variables, or parameters. The purpose of parametric estimation, according to Melin (1994), is to provide a detailed estimate that can conform to a standard work breakdown structure, such as a building system index. A vital variable for this method is the experience of the estimator and his judgment, which is highly involved in reaching the result of the cost estimate.

According to Long (2000), the major advantage of using parametric techniques is that they capture major portions of an estimate in a limited amount of time with limited product definition. Additionally, when using some of the more complex parametric models, the estimator is able to encompass the majority of the total product cost with this one method. Since C.E.Rs. are based on actual product cost history, they reflect the impacts of cost growth, schedule changes and engineering changes. There are, however, limitations to this methodology that should be recognized by the estimator. When the C.E.R. captures cost data at a very high level, it will not provide low-level visibility in specific areas.

It could be argued that ABC is another form of parametric modeling. The difference is that a parametric modeling approach relies on historical data, whereas ABC relies on current cost data defined through current cost estimates that consider procurement cost and resource demands. Project cost plans would be relevant because they are near to real-time costs (Jianyun and Yang, 2011).

Bottom-up estimating identifies the individual cost of items for each of the detailed items needed within the project. By adding the individual project costs together, it is possible to develop the overall cost for the project. This method is close to the traditional cost-accounting approach but again, the definition of cost is not provided. ABC defines cost in a manner that is different to traditional cost accounting by isolating and re-evaluating indirect costs. In the ABC method, the project is subdivided into distinct measurable activities, or work units. Like the traditional cost management method, activity based cost management is a cost allocation methodology. The same argument was given by Hotngren et al., (2010) who noted that while ABC systems are rather complex and costly to implement, many companies over recent years have adopted ABC systems for a range of reasons.

Conceptual cost estimates are developed at the early stages of projects. Probabilistic cost estimation is one of the commonly used techniques for quantifying uncertainties included in the early cost estimates. Regression analysis is another modeling technique used for conceptual cost estimating. Neural networks are a form of artificial intelligence which could also be used for conceptual cost estimation. One of the most commonly used conceptual cost estimation techniques is the Monte Carlo simulation (Chen et al., 2009).

PMI (2008) states that the construction cost constitutes only a fraction, though a substantial fraction, of the total project cost. However, it is the part of the cost under the control of the construction project manager. The required levels of accuracy of construction cost estimates vary at different stages of project development, ranging from estimated figures in the early stage to reliable figures for budget control prior to construction. Since design decisions made at the beginning stage of a project life cycle are more tentative than those made at a later stage, the cost estimates made at the earlier stage are expected to be less accurate. Generally, the accuracy of a cost estimate will reflect the information available at the time of estimation (Simpson, 2011).

Construction cost estimates may be viewed from different perspectives, and for different usage based on particular requirements. Despite the many types of cost estimates used at different stages of a project, cost estimates can best be classified into three major functional categories according to PMI (2008). A construction cost estimate serves one of the three basic functions: design, bid and control. For establishing the financing of a project, either a design estimate or a bid estimate is used.

1. **Design Estimates.** For the owner, or its designated design professionals, the types of cost estimates encountered run parallel with the planning and design as follows:
    - Screening estimates (or order of magnitude estimates)
    - Preliminary estimates (or conceptual estimates)
    - Detailed estimates (or definitive estimates)
    - Engineer's estimates based on plans and specifications

    For each of these different estimates, the amount of design information available typically increases (Baiyi, 2008).

2. **Bid Estimates.** For the contractor, a bid estimate submitted to the owner, either for competitive bidding or negotiation, consists of a direct construction cost, including field supervision, plus a markup to cover general overhead and profits. The direct cost of construction for bid estimates is usually derived from a combination of the following approaches (Enshassi and Ayyash, 2014):
    - Subcontractor quotations
    - Quantity takeoffs

- Construction procedures.

3. **Control Estimates.** For monitoring the project during construction, a control estimate is derived from available information to establish:
    - Budget estimate for financing
    - Budgeted cost after contracting but prior to construction
    - The estimated cost to completion during the progress of construction.

3.4.1 Design Estimates

In the planning and design stages of a project, various design estimates reflect the progress of the design. At the very early stage, the *screening estimate* or *order of magnitude* estimate is usually made before the facility is designed, and must therefore rely on the cost data of similar facilities built in the past. A *preliminary estimate* or *conceptual estimate* is based on the conceptual design of the facility at the state when the basic technologies for the design are known. The *detailed estimate* or *definitive estimate* is made when the scope of work is clearly defined and the detailed design is in progress so that the essential features of the facility are identifiable. The *engineer's estimate* is based on the completed plans and specifications when they are ready for the owner to solicit bids from construction contractors. In preparing these estimates, the design professional will include expected amounts for contractors' overheads and profits.

The costs associated with a facility may be deconstructed into a hierarchy of levels that are appropriate for the purpose of cost estimation. The level of detail in deconstructing the facility into tasks depends on the type of cost estimate to be prepared. For conceptual estimates, for example, the level of detail in defining tasks is quite coarse; for detailed estimates, the level of detail can be quite fine.

As an example, consider the cost estimates for a proposed bridge across a river. A screening estimate is made for each of the potential alternatives, such as a tied arch bridge or a cantilever truss bridge. As the bridge type is selected and taking as example the technology is chosen to be a tied arch bridge instead of some new bridge form, a preliminary estimate is made on the basis of the layout of the selected bridge form on the basis of the preliminary or conceptual design. When the detailed design has progressed to a point when the essential details are known, a detailed estimate is made on the basis of the well-defined scope of the project. When the detailed plans and specifications are completed, an engineer's estimate can be made on the basis of items and quantities of work.

3.4.2 Bid Estimates

The contractor's bid estimates often reflect the desire of the contractor to secure the job as well as the estimating tools at its disposal. Some contractors have well-established cost estimating procedures, while others do not. Since only the lowest bidder will be the winner of the contract in most bidding contests, any effort devoted to cost estimating is a loss to the contractor who is not a successful bidder. Consequently, the contractor may put in the least amount of possible effort for making a cost estimate if it believes that its chance of success is not high.

If a general contractor intends to use subcontractors in the construction of a facility, he may solicit price quotations for various tasks to be subcontracted to speciality subcontractors. Thus, the general subcontractor will shift the burden of cost estimating to subcontractors. If all or part of the construction is to be undertaken by the general contractor, a bid estimate may be prepared on the basis of the quantity takeoffs from the plans provided by the owner or on the basis of the construction procedures devised by the contractor for implementing the project. For example, the cost of a footing of a certain type and size may be found in commercial publications on cost data which can be used to facilitate cost estimates from quantity takeoffs. However, the contractor may want to assess the actual cost of construction by considering the actual construction procedures to be used and the associated costs if the project is deemed to be different from typical designs. Hence, items such as labour, material and equipment needed to perform various tasks may be used as parameters for the cost estimates.

3.4.3 Control Estimates

Both the owner and the contractor must adopt some baseline for cost control during the construction. For the owner, a *budget estimate* must be adopted early enough for planning long-term financing of the facility. Consequently, the detailed estimate is often used as the budget estimate since it is sufficiently definitive to reflect the project scope, and is available long before the engineer's estimate. As the work progresses, the budgeted cost must be revised periodically to reflect the estimated cost to completion. A revised estimated cost is necessary either because of changing orders initiated by the owner or due to unexpected cost overruns or savings.

For the contractor, the bid estimate is usually regarded as the budget estimate, which will be used for control purposes as well as for planning construction financing. The budgeted cost should also be updated periodically to reflect the estimated cost to completion, as well as to ensure adequate cash flows for the completion of the project.

3.4.4 Unit Cost Method of Estimation

If the design technology for a facility has been specified, the project can be deconstructed into elements at various levels of detail for the purpose of cost estimation. The unit cost for each element in the bill of quantities must be assessed in order to compute the total construction cost. This concept is applicable to both design estimates and bid estimates, although different elements may be selected in the deconstruction (Chou, 2011).

For design estimates, the unit cost method is commonly used when the project is deconstructed into elements at various levels of a hierarchy as follows (PMI, 2008):

1. **Preliminary Estimates**. The project is deconstructed into major structural systems or production equipment items, e.g. the entire floor of a building or a cooling system for a processing plant.
2. **Detailed Estimates**. The project is deconstructed into components of various major systems, i.e., a single floor panel for a building or a heat exchanger for a cooling system.

3. **Engineer's Estimates**. The project is deconstructed into detailed items of various components as warranted by the available cost data. Examples of detailed items are slabs and beams in a floor panel, or the piping and connections for a heat exchanger.

For bid estimates, the unit cost method can also be applied even though the contractor may choose to deconstruct the project into different levels in a hierarchy as follows:

1. **Subcontractor Quotations**: The deconstruction of a project into subcontractor items for quotation involves a minimum amount of work for the general contractor. However, the accuracy of the resulting estimate depends on the reliability of the subcontractors since the general contractor selects one among several contractor quotations submitted for each item of subcontracted work.
2. **Quantity Takeoffs**: The deconstruction of a project into items of quantities that are measured (or *taken off*) from the engineer's plan will result in a procedure like that adopted for a detailed estimate or an engineer's estimate by the design professional. The levels of detail may vary according to the needs of the general contractor and the availability of cost data.
3. **Construction Procedures**: If the construction procedure of a proposed project is used as the basis of a cost estimate, the project may be deconstructed into items such as labour, material and equipment needed to perform various tasks in the projects.

According to the literature Migliaccio et al. (2015) and Narbaev and Marco (2011), a wide range of cost estimation methods are used within organizations and companies to predict and estimate activities, hence a project. Estimates generated utilizing different estimation methods provide different projections of the final cost. These differences may have a significant and measured effect on the project, overall.

The Activity Based Costing (ABC) estimation method is a method assigning the costs based on the activities to match the cost and the resources used, or to be used, to complete those activities. ABS, in comparison with or contradiction to traditional cost estimation methods, assigns costs using the allocation of percentages for overhead costs, also called indirect costs (Masschelein et al., 2012).

According to Raz & Elnathan (1998), the main idea behind the ABC is to justify these indirect costs and allocate them. Based on this aspect it is possible to estimate costs more accurately (Masschelein et al., 2012).

We find ABC mainly as a two stages process. In the first stage, resource costs are assigned costs which correspond to the various types of activities performed by the company. Then, the activity cost is estimated individually based on the total cost of resources divided by the volume of activity performed. In the second stage, activity costs are assigned to the project or services that benefit from them (Raz & Elnathan 1998).

Compared with traditional cost estimating methods, ABC assumes that all activities are proportional to the number of activities, packages or projects produced. In companies where the ABC estimation method has been completed successfully in projects, the managers use ABC to support decisions related to allocation of costs, accept some extra cost items or delete others.

While ABC systems are rather complex and costly to implement, Hotngren et al. (2010) suggest that many companies adopt ABC systems for a range of reasons. Accuracy for individual products is quite difficult to achieve given that labour is rapidly being replaced with automated equipment. Furthermore, companies, when dealing with projects, do not have the luxury of time to make cost adjustments once costing mistakes, which are often caused by technological changes occurring over the recent past, have been detected. At the same time, a lack of accurate measurements from companies leads to bids being lost during the bid process due to hidden costs a failure to detect those activities soon enough to predict their costs accordingly.

Most methods used today need a structure to allocate the cost estimates in a specific form which will be controlled as planned. This common structure that all current estimating methods use is the Work Breakdown Structure (WBS). This structure is an exclusive deconstruction of the project into work elements. Each element can be further deconstructed to the lowest cost estimation level possible. Detailed cost estimation is done from the bottom up, starting with estimates for each of the work packages and summarizing the cost upwards through the structure (Chua et al., 2006; Mueller, 2000).

This is a purely task-oriented structure that serves the basic idea of ABC usage. However, since WBS provides an exhaustive deconstruction at each level, there is no information or provision for activities occurring in any other level apart from the lowest that have been referred to the WBS structure for the project (Siami-Indermoosa et al., 2015; Hassanein et al., 2004).

Regarding early estimates, the probabilistic cost estimation method is commonly used. This method of cost estimates meets and solves at a level of the uncertainties included in early cost estimates. According to Sonmez (2005), this method requires the knowledge and acquisition of historical cost data related to past projects. Then a probability distribution function is selected for the cost data by fitting the data against major theoretical distribution functions.

The probabilistic method may be performed at different levels. In a motorway project for example, we mention as level zero (0) the total cost of the project and level one (1) may include the asphalt work. How does this work? If a probabilistic cost estimation is done at level zero, the only data used are the historical data mentioned above. Then, the cost of each project is modified by adding inflation with the use of historical cost indices. For example, euro/km could be calculated with the adjusted cost data and this data set could be used for the selection of the probability distribution factor. Hence, when this distribution function is selected, cost estimates for different probabilities can be calculated and estimation can be completed with a normal range.

In a sample of 6 motorways located in Greece, for example, we have estimates for the past projects as historical records in level zero. Zero level is the total budget cost.

The range of the cost per km is 700.000, 800.000, 900.000, 1.000.000, 1.100.000 and 1.200.000 accordingly as indicated in Figure 3.1.

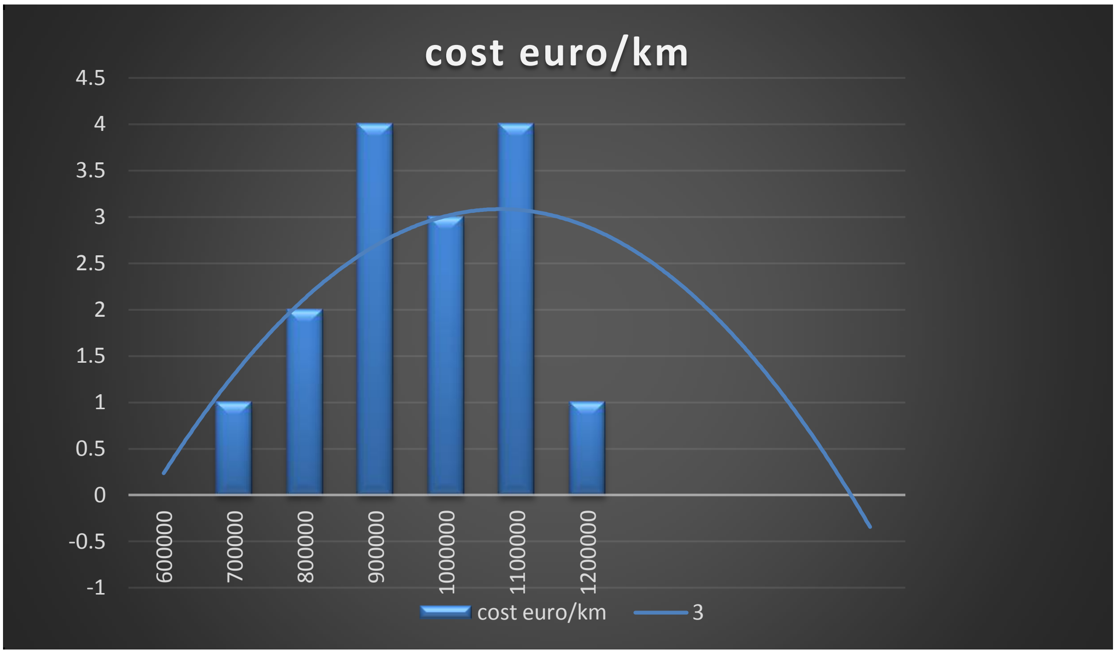


Figure 3.1: MOTORWAY COST PER KM

Therefore, setting the distribution function selected on an algorithm basis, Figure 3.2 provides the result that in 90% of the projects they will be completed with a cost of 900.000 euro/km.

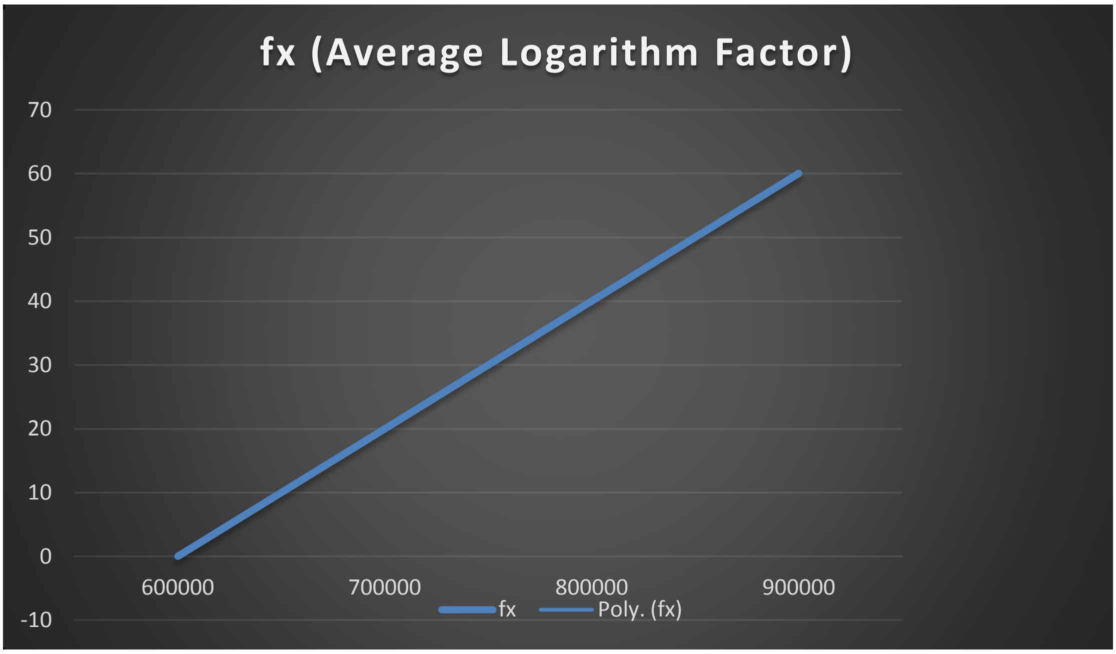


Figure 3.2: AVERAGE LOGARITHM DISTRIBUTION FOR MOTORWAY COST

Methods that provide faster estimates and at generally lower cost they found to be very important in recent times. It is well known that the construction industry is now more competitive in the bidding process than ever before.

3.5 COST MANAGEMENT ASPECTS

In general, a construction cost estimate is prepared to provide the relative costs required to execute a project as planned or programmed. Throughout a project's life cycle, many cost estimates must be prepared (Jrade & Alkass, 2002). These depend on the information gathered from drawings and designs that are issued any stage of the project.

Jrade & Alkass (2002) argued that most literature and research focuses on estimates of the early stages of a project. This is owing to some specific reasons related to the nature of construction projects. In the early stages, managers, with guidance related to early estimates, must make important decisions. Furthermore, the client is aware of the whole picture of the project before these it is constructed, even if early designs have been used in the estimating process or not.

Although the final budget cannot be fixed before the project is completed, the estimates must always be reasonable enough and bear comparison with the actual cost during the construction stage. As explained through the cost estimating methods in Chapter Two, the accuracy of those estimates depends much on the quality and quantity of information available. Time is a crucial issue when this information is released.

The topology of cost management is the result of U.S companies and their efforts to survive among the global competition. Cost management in the construction industry was not the area which concerned the USA, but it was in the manufacturing field where companies moved toward a commitment to excellence. Product quality, high levels of inventories and new workforce policies are some of the aspects of cost management for manufacturing which have played a key role in the recent production revolution.

Kaplan (1984) stated that most companies still are using the same cost management systems that were used or developed decades ago. Today's environment is totally different that of the '80s or '90s; therefore, cost management today requires from innovation and new systems to adapt to the rapid changes in projects. Kaplan (1984) also stated that current measurement systems must consider quality, inventory, productivity, innovation and workforce.

The construction industry adopted all these previous manufacturing cost systems to manage construction projects. It was soon realized that the construction industry has unique conditions which were so complicated the cost management systems simplified many construction factors and started using assumptions instead in each stage of the project.

3.6 BIM AS A TOOL IN COST MANAGEMENT

3.6.1 BIM AS A NEW APPROACH FOR MANAGING PROJECTS, DESIGN DELIVERY SOLUTION

Building Information Modeling (BIM) is essentially a value-creating collaboration through the entire life-cycle of an asset, underpinned by the creation, collation and exchange of shared three dimensional (3D) models and intelligent, structured data attached to them. (UK Building Information Modeling Task Group, 2013)

BIM creates and connects data and information of a product usually within a 3D building model. This allows the operators and the participants to get information and data in a well-structured form for continuous use.

RICS (2015), in his guide for Cost Managers, describes how the key element of the BIM development is the process which, if used properly and is correctly based on plans, designs and specific protocols, could be a successful tool and product for the company.

3.6.2 MANAGING PROJECT COST IN BIM

BIM has emerged as a very powerful tool and set of information technologies that allow the project participants to work on highly technical and comprehensive models using parametric design components and visualize design in 3D (Sunil, 2015).

There is a wide range of BIM measurement software products on the market. The developer needs to choose the model most adjustable to the delivery plan, and set up the formats and the platforms of the software to proceed further in the development (Bernstein, 2012).

BIM deployment earlier in the design process will have a greater influence on cost (Sunil et al., 2015). No matter if the design is in the preliminary stage or final stage, BIM is able to address the design and provide a product based on design details and data. The quality of data used by the traditional cost management methods is one of the major issues. It is essential that a range of information is released in the very early stages and that the designers of the drawings, together with developers of BIM, work together very closely. Any lack of coordination between project processes such as cost management, design and construction cause difficulty in cost estimating and monitoring and controlling. Furthermore, Hanid et al. (2011) argued that the lack of coordination between cost management and the production process results in value loss and inconsistent cost accounting.

BIM acts as a delivery product of the design with very valuable information and data that are extremely helpful for the participants in the project. RICS (2015) in his guide for Cost Managers asserts that BIM embeds and links key asset data with a 3D building model. BIM promotes the sharing of data and key building information in a structured manner for continual use and re-use.

3.6.3 POTENTIALS AND IMPROVEMENT OF BIM IN COST MANAGEMENT

As the estimating information is available, any subsequent processes, like cost and monitoring processes, that rely on this information can also be improved in terms of speed and accuracy. This will enable cost managers to compare alternative design solutions for determining better value for their client.

Autodesk (2007) explains that by using a building information model instead of drawings, the takeoffs, counts, and measurements can be generated directly from the underlying model. Therefore, the information is always consistent with the design. And when a change is made in the design, the change automatically ripples to all related construction documentation and schedules, as well as all the takeoffs, counts, and measurements that are used by the estimator. The time spent by the estimator to create a cost estimate on quantification varies by project. However, although BIM automates a lot of time and labour-intensive tasks, there is still the need for professional input required for making assumptions and assessments (Sunil, 2015; Ballard, 2008; Autodesk, 2007).

There is great potential for improving BIM in design project delivery and providing important information for the project, but there are certain challenges and barriers that prevent BIM become a complete project delivery system (Bingham, 2011).

The cost of BIM implementation, training and the legal system creates doubt that sub-contractors will be involved in BIM (Bingham, 2011; Sunil, 2015). In addition, Wu et al. (2014) found that this limited adoption of BIM is also due to the substandard models, inconsistencies in design information and data exchange tools and formats that are being used in the practice. It is acknowledged that there is considerable inconsistency between design information exchange and the project system methodology to deliver the project itself.

Therefore, even if the BIM is a standardized model used in UK and EU, and effective in delivering a sequence of processes addressing the design product, it is weak in delivering the whole project. BIM is a strong tool in the early stages, but its effectiveness fades in the following stages of the project.

Meadati (2009) has identified that BIM use is limited to design and the early construction stages, and that cost monitoring and control in construction and the post-construction phase presents a substantial challenge without proper BIM support. In this scenario, the pre-construction cost data will be in BIM, but it is ambiguous about how and where the cost data from later project phases will be stored, and located and how easy it will be to perform the cost assessments using the information from BIM and other, as yet unidentified, sources (Sunil, 2015; Kern and Formoso, 2004). Sunil (2015) discussing the post-construction stage, argued that BIM use should be extended to the construction and post-construction phases to realize the full benefits of BIM and cost management. There is a need for detailed research into the challenges and technological implementation of BIM in later project stages.

The lack of knowledge and understanding of BIM among cost managers is preventing BIM adoption and expanded usability in cost management process (Thurairajah and Goucher, 2013; Wu et al., 2014). There is a significant need for investment by the cost management practices in UK to invest in staff training to alleviate this barrier (NBS, 2014).

3.7 CURRENT CONSTRAINTS IN MANAGING PROJECT COST

In most construction projects cost management is related to traditional estimation techniques and cost control procedures and mostly prepared by different people. It is obvious that this traditional approach leads to greater cost of designs than estimated. This inconsistency is wasteful and reduces the value clients get for their money (Doloi, 2013).

Companies often hire professionally educated engineers and surveyors to manage the cost, and those engineers typically require several years to develop expertise in performing the task. Despite this training, owners and contractors find that there is a wide range of construction cost estimates of different estimators for the same project, and that the lack of contingency in the current process often leads to overestimating or underestimating construction costs, resulting in lost opportunities or unexpected expenses, respectively (Staub et al., 2003).

Traditional methods of managing cost have been driven by the design of product and process, rather than serving as criteria for acceptable designs. Cost management has attempted to exert control after budgets are fixed, by after-the-fact monitoring detection of negative variances, and acting to recover to targets (Ballard, 2006; Forbes and Ahmed, 2011).

Existing traditional cost management systems are mostly based on the same long-established principles. Cost information is usually produced too late to be relevant for project management (Kern and Formosso, 2000; Fang et al., 2011).

Successful management of construction cost within the project budget plays a key role in the three roles of construction project management. To achieve this major objective, accurate and reliable cost estimations should be maintained throughout the project lifecycle. There have been three main estimation categories widely utilized in construction management depending on the available information and required accuracy. These three categories that have been referred to in chapter two are: the magnitude estimation, the conceptual estimation and the detail estimation. Since the third category can be achieved only when the detail designs are completed, it is not feasible in the early stages of the project, such as the conceptualizing and planning stages. Thus, conceptual estimating methods are often adopted instead.

The conceptual cost estimation during engineering planning is the most important for construction projects, since the main structural systems, major construction methods, and the most construction materials are determined at that stage.

However, due to the lack of detail design information during the planning stage, the accurate cost estimation becomes a difficult task for the estimator and managers. It was found that the estimators with more experience in the field can do a better job than others with less experience (Amer, 2014).

Unfortunately, an essential difficulty is facing the traditional conceptual cost estimation if the knowledge-based approaches are to be adopted. If the unit prices of the cost items are variable in the marketplace, so the estimation knowledge learned previously may not be readily applicable in future projects.

3.8 IMPROVING COST MANAGEMENT

The literature review has highlighted the need for estimating methodologies to utilize relevant historical data for the estimate developments, yet little research has been carried out on this topic. Construction cost estimating is generally more an organizational problem than an industry problem (Popescu, 2003).

In the construction sector, it has been customary for architects to work with clients to understand what they want, and then produce facility designs intended to deliver the required (Liberatore et al., 2013). The cost of those designs has been estimated, and more often found to be greater than the client is willing or able to bear, requiring designs to be revised, and then re-costed and so on. This cycle of design-estimate-review is wasteful and reduces the clients' value for money. Cost has become an outcome of design (Ballard, 2006).

The integrated cost management, together with target cost application, which will be investigated in the following chapters provides a proactive means for project control and seeks to make cost a driver for design, thereby reducing waste and increasing value. Under this new approach, the estimation stage and control stage are integrated, and share the same goal of maximizing the performance and the value of the project (Bernared, 2006).

An attempt to improve traditional cost management started in the 1960s. The idea of using an operational approach for cost estimating is not new. Skoyles (1965) discussed a radical change in traditional cost estimating methods that has been proposed in the U.K. in which a very detailed estimate of the project was produced based on the early definition of construction methods. Sir Michael Latham's Constructing the Team (1994), the Egan report Rethinking Construction (1998) and the CIOB Code of Practice for Project Management for Construction and Development are some of the crucial reports that supported changes over recent years. The CIOB Code is a significant source of knowledge, with a third edition having been published in 2002. This CIOB initiative involved the formation of a multi-institute task force. The 1991 first edition was referred to by Sir Michael Latham in his report Constructing the Team (1994) as an example of cooperation between the professions (Potts, 2008).

This approach was not successful because it was too time consuming and due to the lack of knowledge of production methods by cost estimating professionals. It seems that the main difficulty for implementing such an approach was the high level of uncertainty and variability that exist in construction at the early stages was neglected. Barnes (1977) proposed a less radical approach to operational cost estimating for construction projects, suggesting the use of different cost drivers for estimating the cost resources, which were classified into fixed, quantity based, time-based, and price based.

Furthermore, Garg et al. (2003) reported that companies have been slow to implement new tools, yet there is broad agreement that current cost systems are not providing accurate enough information. Organizations are loath to adopt new tools and techniques in management accounting to help them resolve problems because they are hindered by economic realities and internal resource constraints, as well as the difficulties involved with changing familiar practices.

In practice, most firms are still using traditional accounting systems even though their faults are well known (Innes et al., 2000; Garg et al., 2003). The problems that prevented the costing systems from adding value to the company were the cost world and the cost per unit attitude that prevailed.

Glad and Becker (1996) described how modern cost estimating systems and information should incorporate the following criteria:

- Provide a multi-dimensional focus on a multiplicity of cost objects such as customers, products, services, functions, processes and activities;
- Focus less on cost tracking and reporting and more on cost planning and control; and
- Support every key business decision, including sourcing, pricing investment justification, efficiency and productivity measures, product elimination and the new product introduction.

This improvement is aimed at eliminating the root problems, and thereby all the unfavourable phenomena that stem from them.

If one accepts that it is to serve the information needs of the design process in an endeavor to facilitate design decision-making by the client and designer, then cost modeling research to date has failed to focus on an issue fundamental to its existence, namely, the communication –effectiveness of the cost planning and control environment within which cost modeling occurs, and the communication-facilitating ability of cost models in the formulation of cost estimate messages.

A new cost management system will cover the gaps of the traditional methodology by integrating the stages in the whole project life cycle. This integration transfers data and valuable information in a continuous dynamic process, improving estimation and control processes and increasing the performance of any project. At the same time, the system will be able to provide feedback in all stages, including the control stage. The stages that this research analyzes are the inception, design, installation and use/operation stages.

A review of existing literature clearly indicates that the main problems for the poor performance of traditional cost management systems are related to flaws in estimating and cost control processes, inadequate information modelling, and the lack of integration of cost management. In addition, there is the fact that measurements finally provided by traditional cost management systems are not linked to the goals and objectives set for each project.

Following the investigation of the above techniques and methods the need for a different cost management approach that will depend on fewer variables than the above techniques, and at the same time would be more reliable in cost comparisons, is clearly justified. However, basic requirements of the existing cost estimation methods are still required and will be used in the new integrated cost management system, not in the traditional platform as they are used today. The planning and control processes will be considered separately, but under the dynamic control of integration and feedback analysis.

The integrated cost management system together with the target cost application, which will be investigated in the following chapters, provides a proactive means for project control and seeks to make cost a driver for design, thereby reducing waste and increasing value. Under this new approach, the estimation stage and control stage are integrated and share the same goal of maximizing the performance and the value of the project.

3.9 MANAGING COST IN THE COMPANY

Based on the literature, managing costs within the company using the right people involved in this situation is a necessity. This process becomes an important factor in modern companies as much as in traditional ones.

To make a clear distinction between managing the costs of the company and managing the costs of projects of the company, it is vital to assume that the company’s central costs are different than the costs of the projects, and somehow these must be measured separately, unless participation of each department of the company and its members in a project has been sanctioned. In implementing real projects, the participation of both central offices and construction sites are needed.

All this should be implemented within the company. In addition, the managing cost within companies should be described and analyzed as an internal mechanism of the organization, with a focus on human knowledge and behaviour.

The mechanism that provides effective delivery of each project relies on teams on the site and teams in central offices. These two teams need to cooperate so that the costs of the project onsite can be transferred and used in the central cost management system of the company.

Human knowledge and behaviour are crucial to managing these costs on a daily basis. Sometimes systems are used where they transfer various cost data from the project site to the central offices and vice versa. Sometimes it is effective, but sometimes it is not. This may be due to a lack of competent people on the site team to manage costs so as to support the company, nor the same among the central company's team to support the onsite project (Fayard et al., 2012).

It is difficult for a system to solve project problems and manage cost if the teams are not well organized towards this aim. The challenge starts with the managers and board of directors who decide whether to risk such an approach. Teams that have practised and learned to work under cost management systems, with the guidance of the project managers, have proved to work effectively.

For the improvement of the new integrated cost management system, which is analyzed in the following chapters, the human factor is generally the key to the gate; there is no estimation if no data can be found and evaluated, there is no control process if there are no people to operate the system or support it with data.

The integrated system is a dynamic system which aims to succeed, but it will fail if people do not get involved in it. Each link in the chain of the system has his own job description and must be aware of the others' job description in order to cooperate more effectively during the project's life cycle. It is vital that a complete channel of communication is established within the company based on rules provided by the project delivery system. These rules give the participants the opportunity to contribute to the system and support the system in delivering the project.

3.10 LITERATURE REVIEW ANALYSIS

Chapter three is the second chapter of the two that analyzes the literature review of managing construction cost. Through the literature, and the description and comparison of various cost estimating methods, it has been shown that each specific method has its own advantages and disadvantages depending on the stage of the project delivery that occurs and the available resources or data available for the project. Even though the ABC method has many advantages, and is widely used by companies, it cannot integrate the whole process and it is extremely costly in its implementation.

Regarding the parametric method, even if the period used for preparing the estimates is reduced, it is not accurate and cannot be used as an integrated process; however, it does have features that could be used in the new integrated cost management system (Bajaj et al., 2002; Long, 2000).

Hence, the literature tells that, within companies, a wide range of cost estimation methods are used to prepare the estimates. At different stages, and with different people, companies use different estimation methods and this leads to different projections of cost which may have significant measured effects on a given project.

Vojinovic (2000) stated that there are several types of estimates prepared by various authors, companies and organizations. It can also be seen that in the industry today, due to the highly competitive bidding process, companies use methods that provide faster estimates and incur lower costs, an approach that will not solve dynamic problems inherent in the project.

The literature shows that most of the known research focuses on the early stages of a project, mostly because it is in the early stages that managers take important decisions, and clients need to gain the whole picture of the project as early as possible.

Nowadays, companies still use these old techniques; as highlighted by Kaplan (1984), who points out that the same cost management systems are used today as were used decades ago.

Another key finding is the fact that the construction industry has adopted previous manufacturing systems to manage projects without taking into consideration the industry's unique conditions, which are extremely complicated. Kaplan (1984) noted that cost management suffers from been innovated, and the introduction of new systems to adopt the rapid changes in projects.

The constraints in managing project cost are also a key finding in this literature. Companies prepare multiple estimates with different people, and the lack of contingency in a project may lead to unwanted outcomes. As Staub et al., (2003) argued, this lack may lead to overestimating or underestimating, resulting in unexpected costs.

The most important limitation is that traditional methods have been driven by the design as a product, rather than serving criteria for acceptable designs. As Ballard (2006) argued, cost management has attempted to exert control after budgets are fixed. That means, cost information is usually produced too late and it is too aggregated and too distorted to be relevant in general principles of project cost management.

The literature review defined and identified the fact that the CPM and PERT principles and methods, which are the origin of cost management, are still used today, and generally the construction industry has spent an enormous amount of time and money developing techniques related to cost management: it may be worth asking if these investments have paid off or not. It is noticeable that very little material is available that supports the investment in project scheduling tools and methods.

Spicer (1992) claimed that there has been a remarkable resurgence of interest in both practice and theory of cost management today and this is because of the shortcomings of traditional cost management.

The literature highlighted the need to provide a different perspective in managing costs in projects. As Popescu (2003) argued, it is more of an organizational problem than an industry problem. This approach is also supported by Ballard (2006) who reported that the cost of designs produced for the clients is far greater than clients are willing to pay, and that leads to a cycle of re-costing and re-submission. This cycle of design-cost is wasteful and reduces the clients' value for money.

The proposed integrated system that is described in later chapters provides a proactive means for project control and seeks to make cost a driver for design, thereby reducing waste and increasing value. Under this approach the estimation and control stages are integrated, sharing the same goal and maximizing the performance and the value of the project.

Efforts of improvement have been found from some companies (Garg et al., 2003), but who also reported that they were slow to implement new tools and methods. Most companies still practice traditional approaches (Iness et al., 2003), Even though Glad (1996) described the criteria that cost management systems should follow, instead limited or no proved records found to be direction of integration systems. Current research as a whole needs to move towards in the direction of integrated planning and control stages.

The new integrated cost management system will cover the gaps created by the traditional methods by using integration as a dynamic process. The poor performances, lack of integration and lack of help offered to managers for decision making that are the common features of the traditional approaches, will be eliminated with the use of an integrated cost management system. The new proposal will become part of a company's internal mechanism and act as a functional operation in how it manages projects and relies on teams and personal behaviour. The human factor is the key factor in cost management performance because it is inherent.

3.11 SUMMARY

The literature has highlighted the effort and time spent in original cost management methods. It is has shown that huge developments have taken place over the past fifty years.

Based on Skitmore and Willcock (1994), evidence has shown that estimators avoid preparing estimates based on real problems in order to present more acceptable forecasts.

The investigation of cost management literature revealed the entire theoretical basis for the principles of cost management processes. It shows that much practice, research and interest is found today which is needed to meet the increased rhythm of the rapidly changing environment.

The types of cost management methods investigated - analogous, resource cost, bottom-up - have unique characteristics, each one has benefits and potential. Still, this is a limited approach that does not lead to a cost management system, but only to what is referred to as a technique. The fact that these methods can be used as bid, design or control estimates, does not solve the uncertainty issues and the risks of delivering projects. More likely, the risks are increased by using these methods.

An essential part of the investigation was the analysis of the concepts of the Building Information Model (BIM). Even though BIM has become a modern tool for delivering a product of design, it is also found to be inadequate in supporting the needs of developing a complete integrated cost management system.

BIM is mainly found being applied in the early stages of the bid and design stage, and usually fades in the following stages of the project life cycle. The project is a product and a process at the same time, and BIM needs to be improved to meet the process function. As defined, BIM application should be extended to the construction and post-construction phases to realize the full benefits of BIM and cost management.

There is a need for detailed research into the challenges and technological implications arising in later project stages.

Therefore, based on the literature, even if BIM is a model to deliver and address the design product, it is weak in the process of delivering the project, and this weakness is found in the later stages of the project.

The literature supported the approach that the existing traditional cost management systems are based mostly on the same principles established in the past and that they cannot solve the modern risks and uncertainties in today's global environment.

Recognising the weaknesses, the need to move towards to an improved way of estimating, control and managing cost must be considered. The challenge is to make all the methods work in all the stages and share the same goal, which cannot be different from that of the project delivery.

This organizational problem must be solved within companies. Companies must adopt an improved way of managing projects. The New Integrated Cost Management System can become part of their processes.

CHAPTER FOUR: RESEARCH METHODS

4.1 OVERVIEW

This chapter describes the methodology and research methods adopted to investigate and develop the integrated cost management system. The methodology used has a purpose to meet and achieve the objectives of the research.

The chapter is divided into two main parts on how the research has been designed and conducted to meet the objectives, and finally the aim. The first part describes the literature on research design and implementation by reviewing the philosophy and data collection methods. This is important for the selection of the most appropriate technique to implement the research. The second part describes the adopted methods, approaches and strategies, and how this research was conducted.

The chapter analyzes the philosophical approach from an ontological perspective, where the area of research is associated with reality and epistemology following the description of the two main epistemological positions: positivism and interpretivism.

This chapter will describe the two main theories of forming the reasoning in this research: deductive and inductive. Furthermore, it will discuss the two most widely used research methods amongst social researchers as part of their research strategies; the qualitative and quantitative methods. A mixed method of research strategies is also described.

The following chapter analyzes the implementation of the research methodology. A literature review of research methodology is covered in this chapter, providing evidence of the gaps found in traditional cost management systems.

The chapter finally describes the selection of methodology adopted and the data collection process and form of analysis employed to meet the objectives, to develop the ICMS-P to the final stage, and to test the reliability and validity of the system.

4.2 METHODOLOGICAL FOUNDATIONS

4.2.1 RESEARCH METHODOLOGY IDENTIFICATION

Methodology could be described as the strategy followed in a whole research period, which uses a clear system and approach to achieve all the objectives of the research.

The literature review on existing traditional cost management processes highlighted the research gaps which contribute to defining the aim and objectives described in section 1.4. The research questions and the research gaps in traditional approaches have provided the need for further investigation, and propose an alternative through this research.

4.2.2 RESEARCH METHODOLOGY

This section explains the research methodology adopted to achieve the research aim and objectives. Because of the importance understanding the research process and the need to select the appropriate approach for this research, an analysis of research approaches has been conducted. In order to make sure that the most suitable research methodology was chosen and that every objective was achieved using the appropriate method, the factors used for choosing the research methodology were established and the relationship between the research objectives and research methods was illustrated.

The research process could be defined as a systematic investigation to establish facts or principles. Most of the different types of research provide the following process as the main basic steps of any given research conducted, as extracted from Howard and Sharp (1983).

- Choose and define the topic of research
- Investigate research areas and rationale
- Design a study
- Collect data
- Analyse data
- Draw up findings and conclusions

- Propose recommendations for following phases

These steps simplify the whole process and clearly represent the necessary activities to be undertaken.

Redmen & Mory (2009), define research as a systematized effort to gain new knowledge. According to Clifford Woody (Kothari, 2004), research comprises defining and redefining problems, formulating hypothesis or suggested solutions; collecting, organizing and evaluating data; making deductions and reaching conclusions; and at last carefully testing the conclusions to determine whether they fit the formulating hypothesis

Research Methodology is a way to find out the result of a given problem on a specific matter or problem that is also referred as a research problem. In methodology, the researcher uses different criteria for solving the given research problem. Different sources use different methods for solving the problem. If we think about the word “methodology”, it is the way of researching or solving the research problem (Industrial Research Institute, 2010).

Methodology can also be described as the research procedure, process and strategy, and approach and method used to achieve the objectives, and thus the aim of the research. The methodology and the structure of research methodology has been widely adopted to guide researchers. Methodology can provide theoretical and practical knowledge to the subject and the research as a whole. The framework of methodology must be constructive enough so it can contribute to the wider knowledge of research content, and provide valuable information not only on this research, but also for subsequent research. All of these functions are set within a systematic pattern which allows the research community to conduct research studies. Figure 4.1 shows the research plan sequence described by Howard and Sharp (1983).

Figure 4.1: Research Process Methodology (*Source: Howard and Sharp 1983*)

4.3 RESEARCH PARADIGM

4.3.1 ONTOLOGY

The ontological perspective that informs the study is rooted in an area that predominantly is associated with reality (Saunders et al., 2011; Bryman, 2012; Easterby-Smith et al., 2012). Ontology definitions encompass philosophical thinking about the nature and existence of the world (Walliman, 2006). Reich (1994) stated that the major ontological questions are; what do we know about the world and is our knowledge a reflection of our interpretation or an abstract?. According to Walliman (2006) and Bryman (2012), ontology can be considered from two perspectives; objectivism and constructionism. Objectivism looks at social phenomena as an independent existence and it is not affected by any other social actors; whereas a constructionist believes that the social interaction among social phenomena causes continual changes to them. Objectivists believe in existential independence in each social entity without it being affected by social actors

(Saunders et al., 2011; Bryman, 2012). Bernstein (2011) defines objectivism as permanent, a -historical matrix or framework to which one can ultimately appeal in determining the nature of rationality, knowledge, truth, reality, goodness, or rightness. This can be interpreted as comparing the outcome of research with an existing case in the design world in the design process to justify the conclusion. Objectivism can be applied to this research by comparing spent time among designers to determine a set of output.

4.3.2 EPISTEMOLOGY

Epistemology is about how we know things and what we can regard as acceptable knowledge in a discipline (Walliman, 2006). It deals with a set of assumptions that assist in the exploration of the philosophical worldview in the study. Therefore, the most agreed and important knowledge can be highlighted and applied within the scope of the study (Saunders et al., 2011). Easterby-Smith et al. (2012) regard epistemology as a general set of assumptions about the best way of exploring the nature of the world. There are two dominant epistemological positions: positivism and interpretivism.

Positivism is about using natural scientific methods in the study of social sciences (Flick, 2006; Walliman, 2006; Bryman, 2012). Bryman (2012) defines positivism as an epistemological position that advocates the application of methods of natural sciences to the study of social reality and beyond. The positivist takes the view that reality can be observed and studied while, in contrast, an interpretivist holds the view that reality is only arrived at by interpreting such phenomena.

Interpretivism is defined as the recognition that subjective meaning plays a crucial role in a social action (Walliman, 2006). Culture and history of past events are used to interpret the social world in social science research. From an interpretive perspective, the world view of the participants is being taken into account (Saunders et al., 2011), which is in contrast with positivism (Bryman, 2012).

The epistemological stance adopted for this research is based on positivism. This is because the design activities in a design office are observed via video recording techniques. The conducted data are revised and coded in order to specify time spent by participants during the design process. Then, the coded data are analyzed statistically.

4.4 FORM OF REASONING

Research theory provides an insight into how to design a research question, select a sample group and which related data to obtain, form a basis for understanding the data, and outline fundamental factors. Theory provides reasons for phenomena or events (Robson, 2011). Creswell (2013) declares that a theory is an interrelated sets of constructs or variables formed into a proposition, or hypothesis, that specify the relationship among variables (in terms of magnitude and direction). Hence, theories, through theoretical analysis, give structure to a series of events and phenomena that are unstructured and unformed. A good research theory gives a clear idea of problems or social issues to the researcher, and highlights the most important part of collected data to extract an appropriate result for the study. There are two main approaches to forming the reasoning aspect: deductive and inductive (Schwandt, 2007; Bryman, 2012). Gray (2009) states that through the inductive approach, correlations among variables are examined and analysed; whereas the deductive approach starts from a theory to reach an effective hypothesis regarding relationships between variables.

4.4.1 INDUCTIVE RESEARCH

According to Bryman (2012), researchers gather data in order to investigate a phenomenon and then create a theoretical framework to ratify the results of the data collected. Researchers that adopt inductive reasoning tend to understand the veracity within the framework of the study, and subsequently devise theories out of the information gathered. Because of the researcher’s limitations, the inductive technique utilizes a much smaller sample for the study than the deductive technique. Also an inductive exploration approach leans closer towards the qualitative analysis technique and uses a range of approaches to collect data so as to establish diverse perspectives.

4.4.2 DEDUCTIVE RESEARCH

Deductive theory is more concerned with obtaining specific data out of general data. In this regard, Chin et al. (2008) argue that deductive theory moves from more general information to specific data. The deductive approach applies when the researcher starts from an assumption based on a literature review and leads it to planning a strategy and then testing and validating the assumption (Bryman, 2012; Gill and Johnson, 2002). In this method, research questions are developed and then validated by being tested (Gray, 2009; Bryman, 2012). Deductive theory is connected to a quantitative research approach where the relationships between variables are characterized by the use of numerical data. Thus, this research has implemented the deductive theory approach to collect information and exploit the result of the data analysis to improve the framework and subsequently scrutinize the framework to certify authenticity.

4.5 RESEARCH STRATEGIES

The most widely used research methods amongst social science researchers remain the qualitative and quantitative methods; these are generally presented as two vying options (Creswell, 2013; Bryman, 2012; Blaxter et al., 2010; Fellows and Liu, 2009). Furthermore, according to Creswell (2013), these two approaches ought not to be considered as converse because they present distinctive perspectives to the research background. Various authors also debate that the disparities between qualitative and quantitative research methods depend on their epistemological base. Table 4.1 below highlights the dissimilarities between qualitative and quantitative research approaches. The most obvious difference between them is the nature of data and approach employed for the collection of the data. Qualitative methods of collecting and analysing data are established using words "arguments and/or flexible questions" (conducting interviews), while the quantitative method is structured/conducted by utilising statistics or using quantitative postulations.

4.5.1 QUANTITATIVE

The quantitative research approach generally involves undertaking a more pragmatic research where data collected are numerical. Creswell (2013) and Bryman (2012) considered quantitative research, as useful for investigating different magnitudes of analysing objective concepts by studying the connections between data collected. The data collected is subsequently measured and examined using advanced tools to determine the 'how' and the 'what', and then evaluated by employing statistical methods (Easterby-Smith et al., 2012; Creswell, 2013). The authenticity of quantitative approaches to research is frequently interrelated to the scope and size of the sample (usually on a large-scale) to define the set of data. Blaxter et al. (2010) dispute that quantitative research refers to the gathering of 'facts' that are genuine, as numbers lean more towards greater accuracy, thus signifying an adjective conclusion of the study. An explicit feature of this approach to research is that the author remains objective and distant from the research procedure (Coombes, 2001). According to Robson (2011), several specific features of quantitative research approaches acknowledged by various authors include: quantification turns the data into numbers and statistics; an investigation into human activities people either say or do; the scientific approach is adhered to, as would be done in a physics or chemistry experiment, for example. The quantitative research approach is most closely associated with the positivist paradigm. Quantitative methods are focused on measuring and seek to convert the observations made into numbers that can be statistically analysed (Punch, 2013). The association with the positivist paradigm, and thus the aim to improve the activity time definition for design tasks, means that quantitative approaches are systematic, objective, and when repeated should be expected to give the same results. In keeping with a positivist paradigm and as the nature of this work is time study, a quantitative methodology is adopted for the main study.

4.5.2 QUALITATIVE

Qualitative research consists of empirical research where there is no numerical data, along with focusing on theory generation (Bryman, 2012). It is an empirical research where collecting and analysing data are chiefly as non-numeric as possible (Blaxter et al., 2010). In another study, Fellows and Liu (2009) state that the qualitative methods seek to gain insights and to understand people's understandings, opinions, and so the views of people are investigated. Therefore, qualitative study means to research, recognize and understand the separate entities in social issues (Creswell, 2013). Table 4.1 presents some differences between qualitative and quantitative research methods provided by Bryman (2012) and Blaxter et al. (2010).

Table 4.1: Some differences between qualitative and quantitative research methods (adopted from Blaxter et al. (2010) and Bryman (2012))

Qualitative paradigm	Quantitative paradigm
Inductive: generation of theory	Deductive: testing of theory
Concerned with understanding behaviour from actor's own frames of reference	Seeks the facts/causes of social phenomena
Interpretivism	Natural science model, in particular positivism
Naturalistic and uncontrolled observation	Obstructive and controlled measurement
Constructionism and Subjective	Objectivism
Close to the data: the 'insider' perspective	Removed from the data: the 'outsider' perspective
Grounded, discovery oriented, exploratory, expansionist, descriptive, inductive	Ungrounded, verification oriented, reductionist, hypothetico-deductive
Process-oriented	Outcome-oriented
Valid: real, rich, deep data	Reliable: hard and replicable data
Un-generalizable: single case studies	Generalisable: multiple case studies
Holistic	Particularistic
Assumes a dynamic reality	Assumes a stable reality

In the qualitative method, the investigator has social interaction with individuals during the process (Coombes, 2001). This method of research tends more to follow the inductive style, which involves concentration on individuals and interpretation (Creswell, 2013). Robson (2011) identified other characteristics of qualitative research which are: the verbal presentation of findings which are less numerical, applying an inductive approach to data collection and analysis.

Qualitative approaches are inherently subjective and closely associated with both interpretivism and constructivism paradigms in so much that they seek to explain individual occurrences. Qualitative data are typically words, or possibly images (Punch, 2013).

4.5.3 MIXED METHODS

The combination of these two methods, quantitative and qualitative, is known as mixed method or triangulation. This method blends quantitative and qualitative methods in a different procedure from simple to complex form (Saunders et al., 2011; Creswell, 2013). The potential of using both quantitative and qualitative methods of data collection and analysis in a single study provides researchers with the opportunity of having a deeper understanding of outcomes. Creswell (2013), classified mixed method strategy into sequential mixed method, concurrent mixed method and transformative mixed method.

The sequential method enables the researcher to develop results of one method with another method. According to Creswell (2013), it could start with the qualitative method and be followed by the quantitative approach, and conversely. With concurrent mixed methods, the investigator uses both quantitative and qualitative methods during the progress of the research (Saunders et al., 2011). With this method, both sets of results are analysed simultaneously to deliver a wide-ranging response to the research questions (Creswell, 2013). The transformative mixed method establishes a theoretical base that uses both quantitative and qualitative data. This theoretical base would then provide “a framework for methods for collecting data, and outcomes or changes anticipated by the study” (Creswell, 2013). Within this base, these could be a data collection method that comprises a sequential or concurrent method.

4.6 RESEARCH TYPES

4.6.1 RESEARCH APPLICATION APPROACH

The reason for conducting research can be classified based on how the research will be used. The "how" question is answered through the basic and applied approach. Even if the basic research and applied research are varied based on the intent of the research, as Goddard and Melville (2004) argued, or varied based on the origin of the problem, according to Drenth et al. (1988), both research application approaches add knowledge to the existing base and support the researchers in conducting their research.

4.6.2 PURE (BASIC) RESEARCH APPROACH

The basic research approach advances fundamental knowledge about a general topic. Generally, new scientific ideas use basic research as a research approach.

Bush (2014), in Science the Endless Frontier, says basic research is performed without thought of practical ends. It results in general knowledge and understanding of nature and its laws. The general knowledge provides the means of answering a large number of important practical problems, though it may not give a complete specific answer to any one of them. Basic research leads to new knowledge. It provides scientific capital and creates the fund from which the practical applications of knowledge must be derived.

Guimaraes (2000) argues that basic research advances fundamental knowledge about the world. It focuses on refuting or supporting theories that explain observed phenomena. Pure research is the source of most new scientific ideas and ways of thinking about the world. Basic research generates new ideas, principles, and theories which may not be immediately utilized but, nonetheless, form the basis of progress and development in different fields. Today's computers, for example, could not exist without research in pure mathematics conducted over a century ago, for which there was no known practical application at the time. Basic research rarely helps practitioners directly with their everyday concerns; nevertheless, it stimulates new ways of thinking that have the potential to revolutionize and dramatically improve how practitioners deal with a problem in the future.

4.6.3 APPLIED RESEARCH APPROACH

Goddard and Melville (2004) argued that the applied research approach attempts to solve specific problems and focuses on achieving the task. It is mainly a descriptive research approach, very practical, that answers questions and supports people in making decisions.

Applied research is a form of systematic inquiry involving the practical application of science. Applied research is contrasted with pure research (basic research) in discussions about research ideals, methodologies, programs, and projects (Nills, 2009).

The applied approach answers “how” this research will be used; it attempts to solve a specific problem to accomplish a task.

The essential difference between basic and applied research lies in the freedom permitted the scientist. In applied work, his problem is defined and he looks for the best possible solution based on these conditions. In basic research, he is released of such restrictions; he is confined only by his own imagination and creative ability. His findings form part of the steady advance in fundamental science, with always the chance of a discovery of great significance at a later date (Bush 2014).

4.7 RESEARCH PURPOSE

The reason for conducting research can be classified based on what the research is trying to accomplish and how it will be used. This is answered through exploration, description, correlation and explanation, as Kumar (2005) argued.

4.7.1 DESCRIPTIVE

Shields et al. (2013) described how descriptive research is used to describe characteristics of a population or phenomenon being studied. It does not answer questions about how/when/why the characteristics occurred. Rather it addresses the "what" question

Another view from Ethridge (2004) maintains that descriptive research can be explained as a statement of affairs as they are at present, with the researcher having no control over variables. Moreover, “descriptive research may be characterized as simply the attempt to determine, describe or identify what is, while analytical research attempts to establish why it is that way or how it came to be”.

Descriptive research needs a well-defined subject and requires intensive previous knowledge of the problem and areas of research. Descriptive research uses qualitative and quantitative techniques. Descriptive research can be either quantitative or qualitative. It can involve collections of quantitative information that can be tabulated along a continuum in numerical form, such as scores on a test or the number of times a person chooses to use a certain feature of a multimedia program, or it can describe categories of information such as gender or patterns of interaction when using technology in a group situation. Descriptive research involves gathering data that describe events and then organizes, tabulates, depicts, and describes the data collection (Glass & Hopkins, 1984).

4.7.2 EXPLORATORY

Exploratory research, as the name states, intends merely to explore the research questions and does not intend to offer final and conclusive solutions to existing problems. Conducted in order to determine the nature of the problem, this type of research is not intended to provide conclusive evidence, but helps us to have a better understanding of the problem. When conducting exploratory research, the researcher ought to be willing to change his/her direction as a result of revelation of new data and new insights (Saunders et al., 2012).

The exploration research approach is used for new topic exploration; hence more information is required to learn about it. The less developed an area the more likely that exploration approach should use. Exploratory research needs creativity, deep investigation and analysis of all sources of information. Furthermore, it addresses the “what” question, using qualitative techniques.

The exploratory research approach does not aim to provide the final answers to the research questions, but merely explores the research topic. It has been noted that “exploratory research is the initial research, which forms the basis for more conclusive research. It can even help in determining the research design, sampling methodology and data collection method.” (Singh, 2007).

4.7.3 CORRELATION

Correlation research is a type of non- experimental research in which the researcher measures two variables and assesses the statistical relationship between them with little or no effort to control extraneous variables. In general, a correlation study is a quantitative method of research in which you have 2 or more quantitative variables from the same group of subjects (Jackson, 2012).

4.7.4 EXPLANATION

Brains et al. (2011) described that the goal of the explanatory research is to answer the question of why. Explanatory research attempts to go above and beyond exploratory and descriptive research to identify the actual reasons a phenomenon occurs. Explanatory research mainly builds on both descriptive and explanatory research approaches. This type of research is very complex and the researcher can never be completely certain that there are no other factors influencing the causal relationship, especially when dealing with people's attitudes and motivations

Explanatory research is conducted in order to identify the extent and nature of cause-and-effect relationships. Causal research can be conducted in order to assess impacts of specific changes in existing norms and various processes.

Compared with descriptive research, which involves looking at detailed data through observing subjects, correlation research studies the relationship between variables and the levels of interaction between the variables.

4.8 DATA COLLECTION METHODS

According to Dudovskiy (2016), data collection can be divided into two categories – secondary and primary. Secondary data are a type of data that has already been published in books, newspapers, magazines, journals, online portals. There is an abundance of data available in these sources about any research area. Therefore, application of an appropriate set of criteria to select secondary data to be used in the study plays an important role in terms of increasing the levels of research validity and reliability. Blaxter et al. (2006) also stated that case studies are a type of data collection method as acting as basic reviews for practical analysis of data by researchers.

These criteria include, but are not limited to, date of publication, credentials of the author, reliability of the source, quality of discussions, depth of analyses, extent of contribution of the text to the development of the research area.

Dudovskiy (2016) identified that Primary data collection methods can be divided into two groups: quantitative and qualitative. Quantitative data collection methods are based on mathematical calculations in various formats. Methods of quantitative data collection and analysis include questionnaires with closed-ended questions, methods of correlation and regression, mean, mode and median, and others. Qualitative research methods, on the contrary, do not involve numbers or mathematical calculations. Qualitative research is closely associated with words, sounds, feeling, emotions, colours and other elements that are non-quantifiable.

Qualitative studies aim to ensure a greater level of depth of understanding, and qualitative data collection methods include interviews, questionnaires with open-ended questions, focus groups, observation, case studies. A choice between quantitative or qualitative methods of data collection depends on the area of your research and the nature of the research aims and objectives.

4.8.1 INTERVIEWS

Bryman (2012) identified the interview as the most widely used method of data collection. When conducted, an amount of important data can be collected in a specific period of time. Gray (2009) has argued and highlighted the connection of a successful interview with the skills of the interviewer. This is gained through experience and extensive practice. Denscombe (2007) and Gray (2009) mentioned that interviews can be classified into three different categories: the structured, the unstructured and the semi-structured. The means of collecting interview data could be achieved through phone interviews, face to face meetings, and various other methods. Structured interviews can be strongly related to the quantitative method of research, based on standard formats and questions. At the same time, they can also be used in qualitative research, depending on the results of the discussion.

Boyce and Neal (2006) described that one of the advantages of interviews includes the possibility of collecting detailed information about a research question. In interviews, researchers have direct control while collecting the primary data, and have a chance to clarify certain issues during the process, if the need arises. The disadvantages of interviews are that they have longer time requirements compared to some other primary data collection methods, and there are difficulties associated with arranging an appropriate time with conducting the interviews, especially when these involve people in the industry and during working hours.

4.8.2 OBSERVATIONS

Marshall and Rossman (1989) define observation as "the systematic description of events, behaviours, and artefacts in the social setting chosen for study".

Observation methods are useful to researchers in a variety of ways. They provide researchers with ways of checking for nonverbal expression of feelings, determine who interacts with whom, grasp how participants communicate with each other, and check for how much time is spent on various activities (Schmuck, 1997).

According to Gray (2009), observation is a type of research method which not only includes the participant's observation, but also involves ethnography and research work in the field. In the observational research design, multiple study sites are involved. Observational data can be integrated as auxiliary or confirmatory research. Gray (2009) also describes how observations can be performed through a participant observer or non-participant observer. Under the same approach, DeWalt and DeWalt (2002) believe that "the goal for design of research using participant observation as a method is to develop a holistic understanding of the phenomena under study that is as objective and accurate as possible given the limitations of the method”.

Dudovskiy (2016) identified that the advantages of observation primary data collection method include direct access to research phenomena, high levels of flexibility in terms of application and generation of a permanent record of phenomena to be referred to later if a need arises. At the same time, the observation method is disadvantaged with longer time requirements, high levels of observer bias, and the impact of the observer on primary data, in a way that the presence of the observer may influence the behaviour of the sample group elements.

4.8.3 QUESTIONNAIRES

Depending on the research, sometimes data collection involves many participants, located in different places, and thus becomes a huge challenge because of difficulties of communicating the scale that the research demands.

Maciaszek (2007) argued that the use of questionnaires is an efficient way to gather information from many participants, especially as meetings are extremely difficult to conduct. However, Maciaszek (2007) described how meetings and interviews are more productive compared with questionnaires because of the feedback in data collection. In interviews and meetings, there is always a response or a further question that makes the process more productive and more helpful to the researcher.

Questionnaires can be classified as both quantitative and qualitative depending on the nature of the questions, according to Dudovskiy (2016). Dudovskiy (2016) also described the advantages of questionnaires, which include increased speed of data collection, low or no cost requirements, and higher levels of objectivity compared to many alternative methods of primary data collection. However, questionnaires have certain disadvantages as well, such as the selection of random answer choices by respondents without properly reading the question and the absence of a possibility for researchers to express their additional thoughts about the matter due to the absence of a relevant question. Computer questionnaires, mail questionnaires and phone questionnaire are some of the types of questionnaire that can be conducted today. The potential of technology can expand questionnaires, meetings and interviews and other forms of human contact like never before.

4.8.4 CASE STUDIES

Case studies aim to analyze specific issues within the boundaries of a specific environment, situation or organization (Dudovskiy, 2016).

Through case study methods, a researcher is able to go beyond the quantitative statistical results and understand the behavioural conditions through the actor's perspective. By including both quantitative and qualitative data, a case study helps explain both the process and outcome of a phenomenon through complete observation, reconstruction and analysis of the cases under investigation (Tellis, 1997).

According to Zaidah (2007), the case study method enables a researcher to closely examine the data within a specific context. In most cases, a researcher selects a small geographical area or a very limited number of individuals as the subjects of study. Case studies, in their true essence, explore and investigate contemporary real-life phenomena through detailed contextual analysis of a limited number of events or conditions, and their relationships. Yin (1984) defines the case study research method "as an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used."

According to its design, the case study research method can be divided into three categories: explanatory, descriptive and exploratory (Yin, 1984 and Dudovskiy 2016)

In more detail, Yin (1984) described that explanatory case studies aim to answer 'how' or 'why' questions with little control on behalf of the researcher over the occurrence of events. This type of case studies focuses on phenomena within the context of real-life situations.

Dudovskiy (2016) explained that descriptive case studies aim to analyze the sequence of interpersonal events after a certain amount of time has passed. Case studies belonging to this category usually describe culture or sub-culture, and they attempt to discover the key phenomena. Exploratory case studies aim to find answers to the questions of 'what' or 'who'. The exploratory case study data collection method is often accompanied by additional data collection method(s) such as interviews, questionnaires, experiments.

The advantages of the case study method include data collection and analysis within the context of the phenomenon, integration of qualitative and quantitative data in data analysis, and the ability to capture complexities of real-life situations so that the phenomenon can be studied in greater levels of depth. Case studies do have certain disadvantages that may include lack of rigour, challenges associated with data analysis and very little basis for generalizations of findings and conclusions.

4.8.5 DATA ANALYSIS

Research requires collecting and then analyzing that data. According to Cresswell (2013), this provides a standardized way of making sense of the data. Data analysis is concerned with analyzing and interpreting the collected data. Dudovskiy (2016) described how data analysis can use both a qualitative and quantitative approach. The first deals with numbers, and second with words. Both have their own nature and different analysis techniques. In qualitative research, using interviews, focus groups, experiments, etc., data analysis is going to involve identifying common patterns within the responses and critically analyzing them in order to achieve research aims and objectives. Data analysis for quantitative studies, on the other hand, involves critical analysis and interpretation of figures and numbers, and attempts to find a rationale behind the emergence of main findings. Comparisons of primary research findings to the findings of the literature review are critically important for both types of studies – qualitative and quantitative.

Data analysis methods, in the absence of primary data collection, can involve discussing common patterns, as well as controversies within secondary data directly related to the research area. Data analysis should be carried out together with data collection and not necessarily at the end (Hunter and Kelly, 2008).

- For quantitative data, it is essential to understand the different types so the suitable method could be used. Stevens proposed this typology in a 1946 Science article titled "On the theory of scales of measurement":
    - Nominal data coming from counting things and placing them into categories.
    - Ordinal data, almost the same as nominal, but in this case categories are ordered and ranked in a specific relationship and compared with each other.
    - Interval data, almost the same as ordinal, but in this case, categories are ranked on a scale using a known factor among them.
    - Coding data, which transform the raw data into groups where it is more easily to understand.
- Analyzing qualitative data is a desctriptive approach as it is concerned with meanings and mostly with the way people understand the various areas of the research (Gibbs, 2002). Gibbs (2002) described the procedures for making a qualitative data analysis as follows:
    - Preparing qualitative data for analysis is a process in which a variety of data follows different formats like notes, texts, transcripts, etc. All this information is transformed into a common format, suitable for analysis and feedback any time it is needed within the research period.
    - The procedures for analyzing qualitative data consist of the following steps:
        - Coding and categorizing qualitative data by breaking the data into units for analysis.
        - Reflections of the early coding and categories with in-depth revision of the notes and the texts allowing for comments.
        - Development of a set of generalization of data by explaining the theme, and any relationship identified in the data. This generalization will be compared with existing theories or explanations and these will be developed in the findings.

4.8.6 RELIABILITY AND VALIDITY

Reliability and validity is the last activity of the research methodology. Because of their importance, they are used to build the research methodology around them.
Reliability is related to and focuses on issues of measurement. Bryman and Bell (2007), described three different factors of measuring reliability; stability reliability, which is the ability of a concept to stand the test of time when put into question; internal reliability, which comprises the indicators that make up the scale of measurement and which should be consistent during a study; inter-observer consistency is applied when analyzing concepts to gain consistency in the decision making.

According to Wilson (2010), reliability issues are most of the time closely associated with subjectivity and once a researcher adopts a subjective approach towards the study, then the level of reliability of the work is going to be compromised.

Reliability plays a key role in making sure that all the methods used and the findings from data collection and data analysis can be trusted. By using these techniques, information can be presented in a standard format by any researcher or organization. Furthermore, it ensures the methodology adopted really measures what it is intended to measure.

The validity of research can be explained as the extent to which the requirements of scientific research method have been followed during the process of generating research findings. Oliver (2010) considers validity to be a compulsory requirement for all types of studies. There are different forms of research validity. The main ones are specified by Cohen et al (2007) as: content validity, criterion-related validity, construct validity, internal validity, external validity, concurrent validity and face validity. Dudovskiy (2016) described these five categories of validity:
face Validity is the most basic type of validity and it is associated with the highest level of subjectivity because it is not based on any scientific approach. In other words, in this case a test may be specified as valid by a researcher because it may seem as valid, without any in-depth scientific justification. Construct validity relates

to the assessment of the suitability of the measurement tool used to measure the phenomenon being studied. The application of construct validity can be effectively facilitated with the involvement of a panel of 'experts' closely familiar with the measure and the phenomenon. Criterion-Related validity involves a comparison of test results with the outcomes. This specific type of validity correlates the results of assessment with other criteria of assessment. Formative validity refers to the assessment of the effectiveness of the measure in terms of providing information that can be used to improve specific aspects of the phenomenon. Sampling validity (similar to content validity) ensures that the area of coverage of the measure within the research area is appropriate. No measure is able to cover all items and elements within the phenomenon; therefore, important items and elements are selected using a specific pattern of sampling method depending on the aims and objectives of the study.

Research validity can be divided into two groups: internal and external. It can be specified that "internal validity refers to how the research findings match reality, while external validity refers to the extent to which the research findings can be replicated to other environments." (Pelissier, 2008).

4.9 STUDY DESIGN: FOCUS ON METHODOLOGY AND METHODS

As described in previous sections of the chapter, the process of research defines the planning of the work of how research will be conducted. Gray (2009) described that this process involves the selection of techniques to be used for data collection, data analysis and findings.

4.9.1 JUSTIFICATION OF THE RESEARCH METHODOLOGY

The aim of this study is to investigate and establish the essential features and provide a prototype system development and trialing of a cost management system which *integrates* the planning and control stages of the delivery of projects in the construction sector. It being a measurement decision-making tool to measure the delivery of the project based on the amount of effort spent during the project life cycle, means that numerical data are needed. Thus, the data need to be quantified into statistics. In addition, project activity must be investigated and compared to other projects.

The technique used in this study is time study, using field observations and time sheets to achieve a realistic time for the different activities being studied. These can indicate the average rate for a specific task, and subsequently provide a scale to measure the level of performance achieved over a short period of task implementation. As such, the positivist takes the view that reality can be observed and studied, while in comparison an interpretivist holds the view that reality can only be interpreted. As mentioned in Section 4.3.2, this study is a deductive research which starts from an assumption based on the literature review and leads to planning a strategy and then testing and validating the assumption. A deductive theory is normally connected to a quantitative research approach, where the relationships between variables are characterized by use of numerical data.

Based upon the philosophical approach and form of reasoning, a quantitative strategy was deemed most appropriate in the use of data; calculations and equations are used.

The research conducted in this thesis was designed to provide a transformation of practice, of knowledge of how projects could be delivered through the development of a prototype Integrated Cost Management System. After a complete review of the existing methodology, approach, paradigm, strategy and data collection methods, a careful selection has been chosen to meet the objectives and the aim of this research.

Methodologies and strategies were defined by specific circumstances such as; availability of data, access to data and related information, availability of case studies, and the willingness of the participants to cooperate in this process.

Both applied and pure research methods were adopted for the purpose of the research. There is a need for both theoretical and practical inputs to support the investigation and the development of an ICMS-P. Basic research generates new ideas, principles, and theories; ICMS-P is a new approach to delivering construction projects.

The conducted research attempts to solve a practical problem and improve the existing practice of managing cost in construction projects. This requires collecting data from different resources using different techniques to: identify the existing situation, formulate the research problem, investigate opinions, explore other research on the subject, and identify the models available for solving the problem and define their limitations. Therefore, applied research application is needed to identify best practices that can be used to deliver construction projects.

Goddard and Melville (2004) argued that applied research helps focus on achieving the task. It follows the descriptive research approach and supports people to take decisions.

Applied research is a form of systematic inquiry involving the practical application of science, hence applied research has been conducted to develop the ICMS-P as a practical solution to solve the problems related to limitations of existing cost management systems. Pure research has been applied for the additional knowledge to existing literature.

From an ontological stance, the research has adopted the constructionists view, believing that the social interaction among social phenomena causes continual changes to them over time.

The epistemological stance adopted for this research is based on positivism. This is because the design activities in a design office are observed via video recording techniques. Reality can be observed and studied, and construction data covering the construction process is the source of data that can be examined, accordingly. The collected data are revised and coded in order to specify the time spent by participants during the design process. Then, the coded data are analyzed statistically.

The use of different research approaches, determine the study approach.

Chin et al. (2008) argue that the deductive theory moves from more general information to specific data. Hence, this study adopts the deductive approach which starts from generalizations to more specific.

Assumptions based on the literature review have led to a strategy, which was then tested to validate the assumptions. Deductive theory is connected to the quantitative research approach where the relationships between variables are characterized by use of numerical data. Thus, this research has conducted the deductive theory approach to collecting information and exploiting the result of the data analysis to improve the framework, and subsequently scrutinize the framework to certify authenticity.

According to (Punch, (2013), the quantitative research approach is most closely associated with the positivist paradigm. Quantitative methods were focused on measuring and converting the observations made into numbers that can be statistically analyzed. In keeping with a positivist paradigm, and as the nature of this work is a time study, a quantitative methodology is adopted for the main study, but also within the process of data analysis, a qualitative methodology has been adopted in some stages of the research. The mixed methods that have been adopted in some stages of the research have been chosen for a more in-depth analysis and understanding of the results and the data collected.

The descriptive research, as mentioned in the previous section of the chapter, needs a well-defined subject and requires intensive previous knowledge of the problem and areas of research. Both qualitative and quantitative techniques are used from the descriptive approach.

This research adopted, as a main approach, the description and applied approach to achieve and apply its aim and objectives. The choice was driven by the nature of the subject and the intensive previous knowledge required for presenting the problem. Even though for the integrated cost management field, not much research has been done until today, the description approach is the most appropriate to use. On the other hand, because of the need to explore all sources of information from the many areas presented in this research, and before proceeding to the integration part of cost management, the exploration approach is used in the early stages.

By comparing the research aim, the objectives, the characteristics and the different research approaches, the current research is mainly descriptive in nature and has adopted the applied approach to achieve its aim and objectives. Quantitative and qualitative techniques were used for data collection and analysis.

4.9.2 DATA COLLECTION METHODOLOGY ADOPTED LITERATURE REVIEW

As a result of the nature of the research, case studies have been chosen as a means of collecting data and as a strategy to analyze the data used in the ICMS-P. The case studies of a river bridge and a motorway underpass were conducted using observations, interviews and meetings with participants in the construction process. These case studies allow an in-depth examination of the data involved in the process of the ICMS-P. The selection of the case studies was based on the availability of the data, the construction period which was useful to verify the ICMS-P results, and the access of the information on the project data.

The System architecture is based on an internal mechanism, which is analyzed later in this chapter, was formed by inputs, outputs and processes. The essential variables that define the data are set in each of the phases of the internal mechanism and characterize the system and how it works.

Questionnaires were not used in any formal way, but due to the nature of the project and the participation of the author in the management of the project, exchange of information was made through project processes. Spreadsheets, calculations, design information and approvals, project calendars, were part of the daily management of the whole motorway project. Emails and computer attached file information are included as primary and secondary data

Data collection is a principal activity in this research process. Data are collected from different sources, using different methods to achieve certain objectives. This approach is also known as “triangulation” which increases the reliability and validity by verifying findings of data from one source with other sources. Different quantitative and qualitative methods are used in the current research for data collection. Both methods have been adopted as there is no quantification without qualification, and no statistical analysis without interpretation.

The initial approach to understanding the established current knowledge needed to support this study, was carried out through an extensive reading of textbooks, journal papers and conference papers. The choice was driven by the nature of the subject and the intensive previous knowledge required for presenting the problem. Even though, for the integrated cost management field, little research has been done, all existing information needed to be analyzed to explain the problem before proceeding to its solution.

Hence, the literature review covered the analysis of the management of contemporary projects and projects' cost. The hypothesis of the first stage of the literature review describes the differences and variances in projects, and how the different schemes affect the management of those projects. Then, all possible existing traditional methods were described and analytically explained. Various estimates were explained, from inception to completion of the projects, and all limitations were adequately described. The literature review regarding traditional cost management approaches highlights the need to define the process approach to managing beneficially the project cost.

The process approach to managing projects is defined. It is the framework of cost management and the stages regarding cost estimation and cost control procedures.

All the possible cost estimation methods and techniques and how these are used until today have been defined. Also, all the inputs, the requirements for those techniques to make them work, the benefits and the outcomes have also been described.

From this stage of the literature review emerged the flow of the whole project cost life cycle and how this is divided into various forms and methods. From the initial cost estimates, up to cost control, all these steps contribute to the whole process approach to managing projects’ cost.

The literature that is described above was used to meet the first target to establish the current knowledge that supports this study. But this would not be adequate if it did not describe accurately what the proposed integrated cost management system in project delivery is.

The second part of the literature review described the cost management tools and methods, such as bottom-up analysis, ABC method, analogous estimation techniques etc. This cost management framework should be clarified before proceeding with the analysis of the integrated cost management system.

All the methods analyzed and explained objectively exhibited both benefits and drawbacks. Each existing tool and technique provides adequate information of how cost is managed or estimated, and therefore a clear picture has been observed of all the gaps that need to be improved by proposing a new system process rather than a limited tool or method similar to those existing methods.

Finally, the two stages of the literature covered the whole framework and explained where the new integrated system will be applied and established all the gaps and linkages that will be covered with this new approach.

At this stage of the research, observation, the literature review and case studies are used as a main source for data collection. The current topic was identified and chosen by the researcher based on his observations, and academic and working experience in this specific field of project management. During the current investigation, the literature review was considered as an ongoing process to collect data. The literature review was undertaken to gather information to achieve the following objectives; a better understanding of the research topic; avoidance of any duplication of previous work.

Published and unpublished works are reviewed to ensure that every work in this field was collected and reviewed. Textbooks, professional journals and magazines, conference proceedings, dissertations, internet, online databases and technical reports are some of the different sources of information for data collection. The data collection process involved the scanning of relative abstracts and contents from various databases. Collecting recent publications and the latest editions of the relevant materials is a continuous process throughout the research period. No interviews and questionnaires are used in the current stage of research, but their contribution to the research is a subject of investigation as the research is progressing. A large number of publications were retrieved. Refinement was done at all the stages of the literature review regarding the relevance of the reading in order to select the most appropriate and continue the research and drive it towards implementation.

4.9.3 IMPLEMENTATION AND DATA COLLECTION PROCESS AND METHODS

The most common mechanism for data collection used in this research was based on observations of the construction of the project, on the exchange information of with colleagues and other participants within the project, and on multiple meetings related to the project where various tasks and work had been produced and then used for the research purposes.

During the construction period of the project, various progress meetings were held to establish the procedures of the construction based on the Concessioner Agreement of the Motorway Project. These meetings had the purpose of organizing the design control and resources and other technical variables regarding the whole project.

Individual meetings were made on a daily basis. To collect some important primary data to develop the ICMS-P, it was necessary to establish, together with the project manager and the site managers, all the relative information that was needed to describe the items that would be used to evaluate the cost of the structures. These items concern the materials, subcontractors' work and the extra rates of workers, all related to the chosen case studies. This list is called the list of items, can be found in Appendix 7 and is restricted to the Bridge and the Underpass which are described in Chapter 6.

The list of items has the purpose of defining which estimation methods were used for the budget cost of the structures as shown in Appendix 9, which shows the budget description when the integration of the process had been already set. The budget is part of the analysis related to unit prices, subcontractors' contracts, suppliers' contracts and design quantities. Appendix 9 shows the picture before preparing the PIS environment, and is presented together with Appendix 10, which shows the actual cost just before the construction started. The information and data collected from this are valuable for comparison and for the integration process throughout the construction.

Appendix 8 provides primary data for the plants related to the structure. This information was requested from headquarters, and the mechanical engineers of the company provided valuable information for each plant and in a way which could be integrated to the use of the ICMS-P.

In chapter 5 and chapter 6, the preparation of an earth mass haul diagram to establish the transportation and the quantities of the earthworks in compliance with deposit areas is described. This information, shown in Appendix 21, was vital for the ICMS-P implementation since the variables affected the construction of the bridge and the construction of the underpass. This is primary data collected information and for research purposes, the document omitted some information.

Part of the process of collecting data was gathering information from the site regarding the operation of the ICMS-P. Appendices 11, 12 and 13 were prepared after the primary data collection, and are part of the process and data analysis showing the extraction files of personnel, the materials, and the subcontractors allocated in the specific construction stage. These Appendices are primary data in the daily operation of the ICMS-P, acting as information to provide to the system. The format is in excel spreadsheets for the convenience of the users, and the form was developed based on the needs of the ICMS-P procedures.

The data collection policy for the quantitative data was derived from real information from construction sites, through meetings or direct contacts. The qualitative data were derived from managers' experience through meetings and observation from the author's managerial position in a high-ranking construction company in Greece. All the information provided is confidential and used for this research purposes only.

4.9.4 DATA ANALYSIS

As explained in the previous sector of this chapter, the data analysis uses both qualitative and quantitative approaches.

Primary collected data have been examined carefully and coded according to the ICMS-P development needs. Tables 5.2 up to 5.9 are nominal coded data placed in categories for the ICMS-P development. In some cases, where factors are included in those tables, these data are interim, and the factors used are related to the integrated procedure needs of the ICMS-P.

The framework requirements and integrated linkages presented in Table 5.1 are an in-depth analysis and data related to the subject. It is both a qualitative and quantitative approach in that it uses observations and information, gathered over a long time period, that covers all the stages of construction, hence all the stages of cost management. It is a set of generalizations of the data used to explain the relationship between them. This generalization is compared with existing theories on cost management. Furthermore, this analysis is the subject of discussion when the findings from the ICMS-P are completed.

4.9.5 RELIABILITY AND VALIDITY

Reliability and validity is the last activity of the research methodology. Because of their importance, the research methodology is built around them. They play a key role in making sure that all the methods used and the findings from data collection and data analysis are reliable and valid. By using these techniques, information is presented in standard conditions of results, recognised by any researcher or organization. Furthermore, they ensure that the methodology adopted really measures what it is intended to measure.

To establish reliability and validity of the research methods used to achieve the aims and objectives, the following actions were adopted:

- A clear and explicit explanation of the research aim, objectives methodology and methods are provided. The research aim has been clearly set and defined with respect to the development of the integrated system. The objectives, starting from investigation and concluding with the use of the ICMS-P, have been met through the methodology and methods adopted. Data, variables and parameterization are a continuous process to complete the system development.
- The reliability and validity of observation is achieved by a continuous process of collecting and recording data. The data collected, as shown in Appendices 11 to 14, are valuable information needed to develop rates, variables and other parameters needed for integration.
- In order to strengthen the reliability and validity of the case studies and documentary data, the case studies investigated are real constructions that present real construction issues, mostly in a non-linear view. This is important because it proves that the integrated system can be used under real conditions.

To check the reliability and validity of the findings and results of the current research, the following steps have been adopted:

- The research methods were selected on scientific grounds and the aim of the research is achieved.
- The research findings are triangulated with other sources from real construction variables.
- The findings fit the existing knowledge that is established. The final results support the established knowledge in this research because of

the methods and methodology followed. The integrated system's results and findings have been achieved because of the sequence of the methods. Firstly, the frame of the system and its requirements have been established; then the data was collected and parameterized as variables; and finally system was created and applied to real cases. This sequence was very helpful in achieving not only the aim but also the objectives.

The primary data results related to the analysis, and the conclusion was compiled from the findings of the data collected. Existing literature was used to support the research findings. Making recommendations for future research identifies the reliability of the primary data collected. The meetings, the interviews, and the exchange of information, as part of a real project in progress, provided the validity of data collected. Data from different resources were used to explore the outcomes. Theories were explored to develop a solid approach towards the findings. Different research methods were used to explore and develop the results, which showed a very strong connection to the findings.

4.9.6 IMPLEMENTATION OF THE PROPOSED DEVELOPMENT

In previous sections of the chapter, the research methodology was analysed, the methodology selected and the process designated for data collection and process. Current research supports the development of an integrated cost management system which demands a continuous data collection process and analysis throughout the cost management stages. This is described in Chapter 5 as part of the development process.

The research methodology adopted supports any stage of the ICMS-P development.

System Architecture Figure 5.14, Internal Mechanism of ICMS-P Figure 5.12 and Integrated Mechanism System in Project's life cycle Figure 5.13 are products created through the data analysis. PIS environment formats extracted Figures 5.15 up to 5.36

were created in order to develop the ICMS-P, and as part of the data analysis of primary data collected.

The specific methodology of the integrated cost management system leads to a time process - “proposed analyses and solution development” - which is shown in an analytical figure below.

From the literature and observation of systems development, it was found that any system, no matter how integrated it is, needs information and data to operate. It needs data and inputs that must be carefully used to enter the system in all stages.

The design study, which also describes the internal mechanism of inputs, outputs and processing and tools methodology, is followed by the implementation of the study with all the procedures of data collection. Finally, a time process solution development describing all the stages of system development is proposed.

As a system, it should follow some specific rules to be applied and used throughout the system application process. The initial approach of the integrated system was to provide a complete and closed system without gaps or errors in the process which would provide efficient results in the whole project life cycle.

The first question that had to be answered was the “how” question. How was a system as part of the procedure in a project delivery developed? It is well known that cost results are very sensitive, and very important decisions rely on such results. Therefore, the proposed system should be accurate and provide the results when needed in a way that the upper management could use in its decision-making policy.

The research relied on that statement and hypothesis and a decision was made to build two different time processes. The first was the “System Development Time Process-Stages, horizontal axis of System architecture, and the second was the “System Process Time-Internal Mechanism, vertical axis of the System Architecture as presented in Figure 5.14.

The empirical work, together with the literature of systems development and primary data collection, provided all the necessary information to create those three main stages of the ICMS-P.

When developing a system, any researcher or designer of systems must follow certain stages to come to a final output. The situation becomes more complicated when, within this cost management system, integration of information must be developed to support the process of the system. Integration becomes then a dynamic process in order to put together all the information from the estimation stage to the control stage. How is this integration being developed within the system development? When does the system become an integrated system?

These questions have been answered by developing the system in stages: three unique stages working separately, until they become one in a unified integrated cost management system.

The research methodology and ICMS-P development have a stage of verification which is the process from estimation process to control process, with feedback procedures providing specific outcomes. The outcome of the reporting system of the ICMS-P provides all the evidence of validation since all the data have been included in a series of system processes, providing results which are mathematically proved and are valid, as shown in Chapter 6, through the case studies, and Appendices 14 to 17.

4.10 SUMMARY

The chapter presented a review of different research methods adopted for the purpose of conducting the current research. This research adopted a mixed method of research approaches and techniques which helped to improve the data collection process and gain valuable information, both theoretical and using best practices, to conduct this research.

The research conducted was based on the philosophical approach, research strategies, the form of reasoning, research application approaches, research objectives and the data collection process, and case studies. All these qualitative and quantitative techniques and methods of research had one purpose: to meet the objectives, hence the aim, and conduct the research. The aim is clear and direct and the objectives chosen to meet and achieve the aim, are adequate in terms of quantity; six objectives cover the need to develop a system. The objectives cover all the needs in terms of literature investigation and findings, they proved the initial hypothesis of the gaps of traditional project management systems and support and justify clearly this hypothesis. The objectives cover the cost management processes, the investigation, and the development of the system, first as a prototype and then as a verified and valid integrated system.

The choice of description and applied approach to meet the aim and the objectives was driven by the nature of the subject and the knowledge required presenting the problem and the current situation.

A key factor in choosing the methodology was the fact that it was necessary to explore all sources of information for the many different areas presented in this research; The difficulty was that for the integrated cost management field not much research has been conducted until now. Based on this, the description approach is also being used as the most appropriate for the specific field.

Finally, this methodology succeeded in meeting the final objectives of developing the integrated cost management system, which is also the aim of the current research.

Methodologically, the next stage of the research is the implementation of the research described in this chapter by describing the ICMS-P development and the case studies.

CHAPTER FIVE: ICMS-P SYSTEM DEVELOPMENT-ANALYSIS AND RESULTS

5.1 OVERVIEW

The current chapter focuses on the integrated cost management system development and its application.

The chapter begins with the analysis of the benefits and the outcomes of such a system, and how useful it would be to improve the project performance, solve the current poor communication problems and reduce the cost uncertainties in construction projects. The main working packages are the investigation, the analysis and the definition of requirements of such an integrated system, the benefits and the requirements of using Project Information System (PIS) and Enterprise Resource Planning (ERP) systems to support the integration process, the development of a prototype framework of the system, the development of the Integrated Cost Management System, the application of the system through a model development, and finally the revision of the process.

The following is analyzed in the chapter: what this new integrated cost management system is, what its functional process is, and how the two main stages of planning and control stage are integrated by explaining the transfer of data and valuable information through a dynamic and continuous environment.

The description of the PIS in the following chapter explains the environment where the integrated system would be applied.

The chapter continues with highlights of the proposed integrated system. After a short description of the main ideas of the integrated system, the system development itself is shown in stages.

Finally, the contribution of the integrated cost management system to the project's delivery process and the innovation areas of the system and the key findings are described.

5.2 ICMS-P: Outline Description

The integration system is analyzed in this chapter in following sections:

- System concept
- PIS Environment
- Proposed ICMS-P
    - Framework requirements and characteristics of the system
    - Internal Mechanism of the system
    - Integrated Mechanism of the system
    - System architecture
- Stage one: System Integration needs and specifications
- Stage two: Integrated System and application environment
- Stage three: Parameterization and applied Model-Integrated Cost Management System and application

The System Concepts section, provides the author's framework proposal for the processes and linkages of the system. In addition, the benefits of the ICMS-P and the expected outcomes after the development of the system are explained. Finally, the section explains briefly the ICMS-P.

The PIS Environment section highlights the aspects of the PIS that should be involved, including diagrams related to the specifications of the PIS environment for the projects. In the PI Systems, there is always a default structure, and an explanation of how this is being integrated and designed for the integrated processes is given. A WBS analysis is also explained together with the hierarchical levels. This begins with a description of cost categories and how these are affected and used within the WBS structure.

The Proposed ICMS-P section explains the analytical approach of the framework of the system, which includes four main packages or stages. These are explained analytically as follows:

- Design of resources and elements
- Cost estimation

- Constitution of budget cost
- Cost control

Each of these four packages starts with inputs, then techniques and methods used to analyze and calculate those inputs, and finally the output of each specific package/ stage, which acts as information and input for the next stage. Each stage is described separately by analyzing its internal mechanism of the framework and how it works.

As part of the process, the Proposed ICMS-P section describes an example with the fundamental characteristics of a cost estimation and cost control system. This example is analyzed in terms of resources. It is given the hierarchical cost level of activity, the unique ID coding system for each specific activity and unit cost levels together with participation of each activity in cost. Then, cost estimation is measured in a way to be integrated for control process, including all the variables of the specific activity

The Proposed ICMS-P section explains and analyzes the system development design process, which is the heart and the guide to prepare and develop the whole integrated cost management system.

The proposed system has been designed to be completed in three main stages. Each stage works with an interim mechanism, including the integration process, ensuring the integration of all stages of project delivery.

Stage one section describes analytically the cost management framework including all the requirements to proceed with the system and model analysis. That means control policy requirements and control processes like Earned Value Analysis (EVA) or other methods should be structured by that initial stage. This stage is mainly the structure of the integration, defining all the requirements needed before proceeding with integration development.

The second stage section describes the Development of the Integrated Cost Management System as an output of the second stage. All integration linkages are explained and analyzed and described in a specific environment by using PIS processes. All the information structured in stage one is transferred and applied in stage two. All format processes and reporting systems are set up in this stage, which is also called the integration stage. Many extracted figures and tables are being analyzed from the prototype application environment, providing specific requirements and needs to proceed in stage three.

Since the integrated environment with all factors is being set up with the delivery of a prototype model, stage three establishes the parameterization process before budgeting and starting the construction. This process analyzes the factors that are needed to parameterize and meet the uniqueness of each construction or project.

Providing a clear picture of parameterization, an example of a bridge and factors used to construct it is given. All factors are explained and used in the three stages of project delivery accordingly. Stage Three analyzes also the final form of the applied model of the whole system through a reporting system from the application model.

5.3 SYSTEM CONCEPT

Cost Management processes described are used in the project delivery stages from inception to the use stage. According to PMI, "project management is the application of knowledge, skills, tools, and techniques to a broad range of activities in order to meet the requirements of a particular project." There are five phases of project management and if the lifecycle provides a high-level view of the project, the phases are the roadmap to accomplishing it. The phases are: Project Initiation, Project Planning, Project Execution, project Performance/Monitoring and Project Closure.

For research purposes, these stages have been covered in four stages, following the cost management core function, as follows: Design of Resources or Elements, Cost Estimation, Constitution of Budget Cost, and Cost Control. All these four stages cover the five stages described in PMI as a project life cycle

Their integration process that this study analyzes will provide a complete integration cost management system with emphasis on the links between these processes and the feedback from one process to another.

Table 5.1 below provides an overview of the project cost management processes and their links. Initially, the table describes the items in the whole project cost management life cycle, from estimation stage to control stage. These items constitute the framework requirements and characteristics that are used in the Integrated Cost Management System. For research purposes these items do not represent a complete list of inputs and tools and outputs, and for that reason it is referred to as a framework. These are the requirements following the internal mechanism as described with inputs outputs and tools and techniques. These requirements are integrated into all the project life cycle; therefore, they become the essentials for the project implementation. Each item in the following table is described in the stages development later in the chapter.

Table 5.1: Cost management processes and links for integration (Source: Author's proposal)

PROJECT COST MANAGEMENT			
A Design of Resources or Elements	**B Cost Estimating**	**C Cost Budgeting**	**D Cost Control**
.A1 Inputs	**.B1 Inputs**	**.C1 Inputs**	**.D1 Inputs**
WBS	.1 Enterprise environmental factors	.1 Project scope statement	.1 Cost baseline
Activities ID/Elements ID	.2 Organizational process assets	.2 Work breakdown structure	.2 Project funding requirements
Historical data	.3 Project scope statement	.3 WBS dictionary	.3 Performance reports
Project Scope Statement	.4 Work breakdown structure	.4 Activity cost estimates	.4 Work performance information
Description of elements or resources	.5 WBS dictionary	.5 Activity cost estimate detail	.5 Approved change requests
Organizing methodology/Organizational Process Assets	.6 Project management plan	.6 Project Schedule	.6 Project management plan
Estimation of duration of activities	Schedule management plan	.7 Resource Calendars	
Enterprise Environmental Factors	Staffing management plan	.8 Contract	
	Risk register	.9 Cost Management Plan	
. A 2 Tools and Techniques	**. B 2 Tools and Techniques**	**. C 2 Tools and Techniques**	**. D 2 Tools and Techniques**
Estimation of experienced managers	.1 Analogous estimating	.1 Cost aggregation	.1 Cost change control system
Assessment of alternative solutions	.2 Determine resource cost rates	.2 Reserve analysis	.2 Performance measurement analysis
Project management software	.3 Bottom-up estimating	.3 Parametric estimating	.3 Forecasting
	.4 Parametric estimating		.4 Project performance reviews
	.5 Project management software		.5 Project management software
	.6 Vendor bid analysis		.6 Variance management
	.7 Reserve analysis		
	.8 Cost of quality		
. A 3 Outputs	**. B 3 Outputs**	**. C 3 Outputs**	**. D 3 Outputs**
Resources demands	.1 Activity cost estimates	.1 Cost baseline	.1 Cost estimate (updates)
Project Management Plan	.2 Activity cost estimate detail	.2 Project funding requirements	.2 Cost baseline (updates)
Early Activity durations	.3 Requested changes	.3 Cost management plan (updates)	.3 Performance measurements
Risks and threats	.4 Cost management plan (updates)	.4 Requested changes	.4 Forecasted completion
			.5 Requested changes
			.6 Recommended corrective actions
			.7 Organizational process assets (updates)
			.8 Project management plan (updates)

The Proposed integrated system is divided into work packages that should be accomplished and mainly connected with the objectives of the research as follows:

A. Analysis, categorization and presentation of requirements needed to develop the integrated cost management system.
B. Investigation of the benefits of using PIS, ERP systems along the life cycle of the proposed integrated cost management system.
C. Development of the prototype framework of the requirements of the new integrated cost management system within Project Delivery.
D. Review both contractors' and clients' side and highlight the differences within the system requirements and findings.
E. Development of a prototype integrated system.
F. Development of the application model of the ICMS-P.
G. Revision of process with case studies.

5.3.1 BENEFITS

This integrated cost management system is being conducted mainly to provide real and direct benefits:

- To eliminate differences between the cost estimation and cost control processes.
- To reduce the cost uncertainties in construction projects.
- To integrate cost estimation and cost control processes.
- To provide a new way of managing cost in a project delivery.
- To solve poor communication of information linkages that traditional cost management methodology produces.
- To satisfy better the clients' needs.
- Seeks to make cost a driver for design, thereby reducing waste and increasing value.
- To improve managers' and project team's performance.

5.3.2 ICMS-P OUTCOMES

The following outcomes may be expected:

- Cost management system framework requirements within project delivery process.
- A new prototype integrated cost management system process.
- New integrated cost management system development.
- A prototype computerized application system based on the Integrated System together with ERP application environment.
- Recommendations for other systems' development related to more specialized constructions.
- System application in real projects.
- Relevant cost database applicable to any contractor, client or researcher.

5.3.3 PROPOSED INTEGRATED SYSTEM

The proposed cost management system is a unique integration of both planning and control stage in a new cost management system linking the two processes into one with a continuous flow of cost management information and feedback. As explained in the literature review, there is no clear methodology currently that follows the rules of an integration process by using cost management as a core function to deliver a project. All systems and all methods and tools focus on and are specialized in separate areas of cost management and managing cost within a project life cycle (Fayard et al., 2012).

A new cost management system will cover the gaps of the traditional methodology by integrating the stages into the whole project life cycle.

What is the integration process that makes it so important and useful in project delivery? The hypothesis is simple: it describes how a project is going to be delivered, with what cost and what resources. Beyond that, it answers the managers' dilemma of how they will control the costs in the project life cycle, and how the integration process supports their decisions to implement the project.

This integration transfers data and valuable information in a continuous dynamic process, improving the estimation and control process, and increasing the overall performance of any project:

- At the same time the system will be able to provide feedback in all stages including the control stage.
- The integration methodology that has been adopted in the proposed system covers the project stages from inception to operation stage based on an internal mechanism as described in Figure 4.3

The four main stages that we meet in project delivery are the Design of Resources or Elements, Cost Estimation, Constitution of Budget Cost, and Cost Control. Each of these stages has specific characteristics and information that is used in the rest of the stages by transferring the information forwards and backwards. This process of successful transfer of information from one stage to the others, both forwards and backwards, is the integration process of the stages. This process explains how the proposed system works. The emphasis of the integrated system is in the links of these two processes referred and the feedback from one process to the other.

The novelty of the integrated system itself is that there are no boundaries in the process and mainly there are no errors apart from human errors. The more variables the system gets, the more beneficial it will be for the managers. As it will be proved later in the chapter, the results are efficient and valid and always based on information given to run the system. It will be proved that each stage is being used and managed carefully with parameterization of the relevant data and in such a way that these data fit to the next stage under the integration sequence.

The Design of Resources or Elements and Cost estimation are the baseline of the system mechanism. It is the zero point of starting the integration process. Anytime in the procedure, as will be explained in the chapter, the managers or the control managers will be able to evaluate and support the whole procedure the information used. This evaluation helps to realize in real time the omitted information and errors by users, and for that reason a complete Project Information System (PIS) has been used, to provide all this information as a database ready to be recalled whenever needed.

The maximum performance of the system has been achieved with the establishment of the framework of requirements and analysis of the data with any parameterization that occurred.

5.4 Project Information System (PIS) Environment

Developing an integrated system is a process where all aspects must be defined and developed in the first stages. The establishment of all those features, tools and methods will lead to the outcome of the integrated cost management system. One of these aspects must be the information process which will be used to transfer and create all those data in the project delivery process.

Those systems are called Project Information Systems and such a system has been developed in this research to support the whole integration cost management system. Without a project information system, there would be neither reporting information of the results of the process, nor any integrated stages (Perera et al., 2004). PIS is the environment that supports the system development and allows users to work within this environment

The Project Information System (PIS) is an environment in which every activity or information within the project is saved in a database which can be recalled in any stage of the project. PIS combines all the operational and construction activities in a unified process of managing projects. Information can then be used by any member of the project during the design or construction stage (Luo, 2011; Lee et al., 2012). Therefore, what should be achieved is a more reliable economic, cost and functional control system for multiple projects.

Since the cost estimation and cost control system is being developed, another process must be designed to apply this system within a more global Information system for the whole project life cycle. This is called the Project Information System (PIS), and part of this is the cost management system that this analysis investigates. The PIS will define the level of automation of the proposed model, and will generate the software tools needed and the reporting system of the project

Construction projects inevitably generate enormous and complex sets of information. Effectively, managing this bulk of information to ensure its availability and accuracy is an important managerial task. Poor or missing information can readily lead to project delays, uneconomical decisions, or even the complete failure of the desired outcome. For example, there must be unexpected results when an owner and project manager suddenly discover that on the expected delivery date, important facility components have not yet been fabricated and cannot be delivered on time. With better information, the problem could have been identified earlier, so that alternative suppliers might have been located or schedules re-arranged. Both project design and control are crucially dependent upon accurate and timely information, as well as the ability to use this information effectively. At the same time, too much unorganized information presented to managers can result in confusion and paralysis of decision making.

As the project gets underway, the types and extent of the information used by the various organizations involved will change. An example of some important information would include: the cash flow, design documents, construction schedules, cost estimates, quality specifications, contracts, and so many more that the construction industry deals within project implementation processes.

Figure 5.1 describes the project overview and aspects that the PIS is involved in the process. This is an example of the sum of PIS packages. There are many more related to the construction industry, depending on the nature of the project. A contractor or client could use more or less, depending on his needs. Figure 5.1 is a proposed example used for research purposes.

Figure 5.1 Project Information System (PIS) Environment (Source: Author's proposal)

This Project Information System in Figure 5.1 represents a number of aspects of PIS and connections within the project.

Budgeting: the formulation of the budgeting environment process. It is mainly the database of the budget of the system.

Costing: the environment where all the methods and tools used to execute costs in activities are found. In this environment, all the methods (analogical, parameter, ABC estimation, percentages.) are shown.

Procurement policy and purchasing are set up in a specific database.

Subcontractors follow up: the environment where all contracts are used and managed for cost and budget.

Claims: the environment where the initial contracts have been included, and all variances are recorded and categorized according to the project needs.

Machineries/Plant: the list of project plant and other machineries, and how these affect the project. It involves, among others: hourly ratio, fuel, maintenance.

Human resources: the personnel environment, which includes the entire project staff (engineers, supporting staff, operators, labour, drivers, admin staff).

Accounts: the environment involving the accounting office, where all the information needed can be uploaded in real time process

Risk assessment: this environment involves all the risk areas that may possibly occur in the project life cycle. It is a dynamic environment, recording all the risks through the project life cycle.

Site monitoring: the environment which imports the site logs into the cost management system, and exports the framework of the cost control process to fill in construction sites daily, weekly, monthly, according to the project needs.

Primavera Project Server Link: there is almost 100% connection with primavera and other ERP scheduling systems due to the unique ID factors that the integrated cost management system uses. The system transfers information about tasks in both directions, from primavera to Integrated Cost Management System and vice versa.

Project Cost Reports: this is the monitoring and reporting system environment of the System. It involves all the reports that can be extracted that have been designed (stage three of the system). This reporting system is used to inform managers and project control managers and board of directors for decision making policy.

These are the main categories of the PIS, and how this has become a vital part of the Integrated Cost management system that has been developed.

Figure 5.2 shows how the architecture of the structure has been designed, providing a clear understanding of the magnitude of the effort given to design this integrated system adequately.

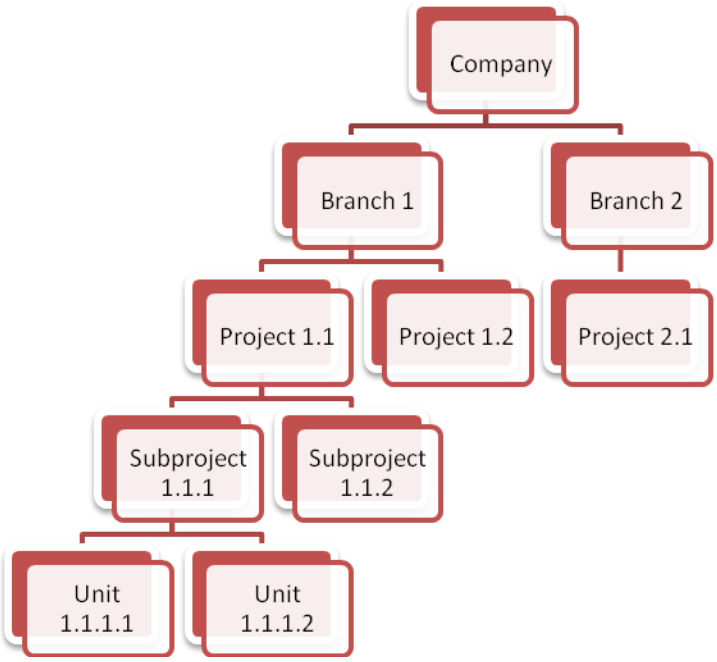


Figure 5.2: Company / Project Analysis Example (Source: Author's proposal)

Figure 5.2.: Starting from the top, the system has been designed to cover the needs of any company, small to large. The methodology that this system uses (without being strict - any company may decide to choose other organizational means to manage their projects, which means the integrated system can be adjusted accordingly) is to divide the company into branches, for instance: highways, buildings, energy, real estate, private housing etc. This division system allows more efficient categorization due to the nature of each simple category within projects. Therefore, the system does not have the need to make two, three or four different codes to explain a specific activity just because this activity could be found in both building and highways as well: only the index possibly would have different a value in those two categories.

In the third level, we meet the projects with a unique ID, matched to their branches, and in the fourth level we meet the subprojects, if the projects are too big to control in one piece. For example, in a multi-scheme project like highways that involved open-air works and tunnels, the project could be divided those two in subprojects. The final level that can be controlled are the units, which mainly refer to different construction sites if the scheme is extended over many kilometres, or the building is divided into units of civil works and units of electromechanical works, or possibly environment works outside the building area, or sewage works, and so on.

Figure 5.3: Typical Tunnel WBS Analysis in levels (Source: Author’s proposal)

An example of tunnel WBS structure is presented in Figure 5.3. It provides an example of the 4th level of a company’s project division. Each task of those shown in Figure 5.3 is categorized and weighted according to the task and the participation of the task in the whole process of construction.

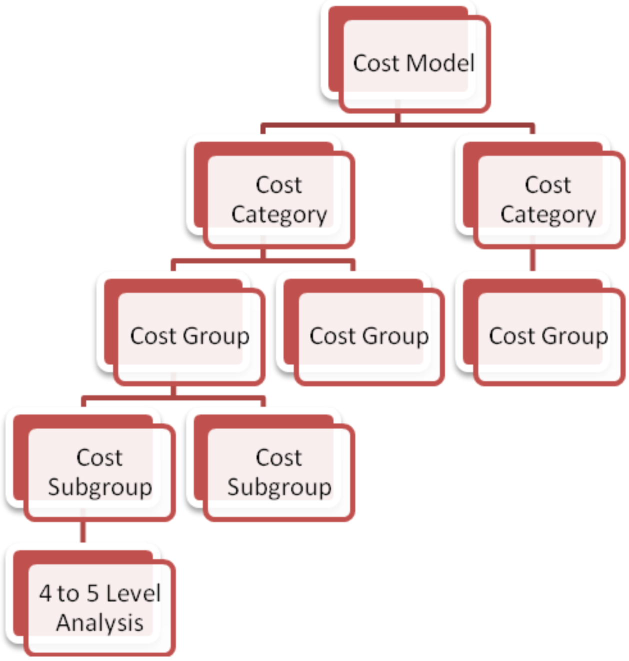


Figure 5.4: Multi-Level Project Cost Analysis (Source: Author's proposal)

Figure 5.4 follows the IS system and its categories until the last costing activity to measure is reached. Cost categories, which are described in the following graph, include materials, subcontractors, and plants. These categories can be divided into groups. For example in materials, two main cost groups could be the concrete and the reinforcement. Concrete could be divided into various subgroups like C20/25, C30/37, Gunite and so on. It is proposed that no more than 4- 5 levels in categories are used due to difficulty in controlling them. This database is valuable because all the unit prices or costs of each category and subcategories have been entered. Hence, this information can be used to prepare the budget for each activity of the project. This database is a valuable tool for future projects, especially in the bid process.

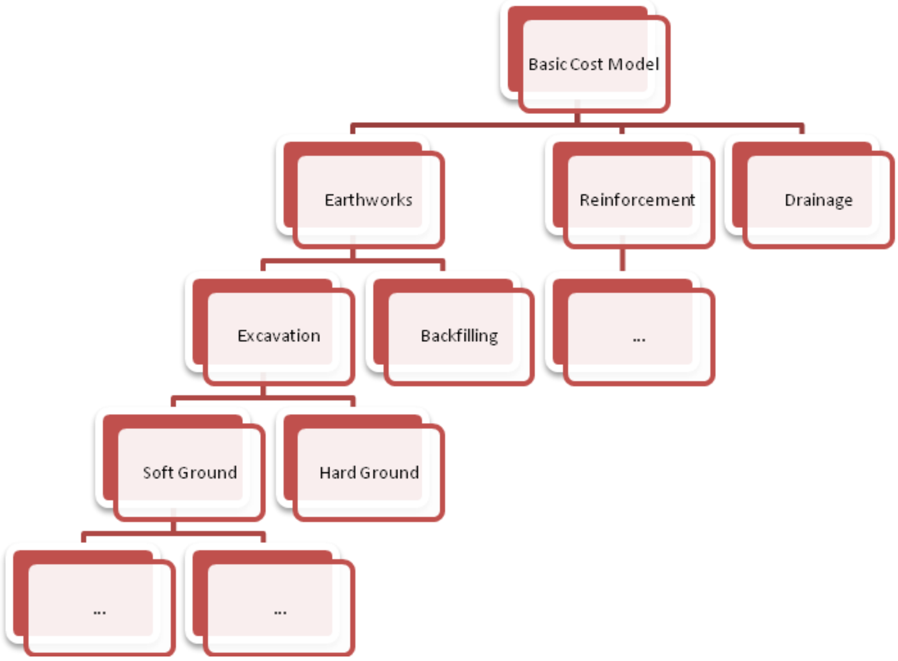


Figure 5.5: Project Cost Analysis Example (Source: Author's proposal)

Figure 5.5 represents a "zoom" section of an example that describes the categorization of activities and packages of activities at all levels. It is clear from this example that every time the system creates the levels of hierarchy, all or most of all parameters have been included.

In this case, some examples in level two, where the earthworks, the reinforcement and drainage works are shown. Earthworks are divided into cuts and fills, or excavations and embankments. Excavations are made in soft or hard ground, or could be assigned some other definition if needed like gravel, rock, or any other soil. For Embankments, the division could be made into levels like 1^{st} layer usually 20cm depth, 2^{nd} layer 20cm depth, 3^{rd} layer etc., up to the level before the pavements (PST and CDF-Capping Layer).

The above categorization is very important when the structure of the system is built because it provides valuable information, either for the estimation process or control process.

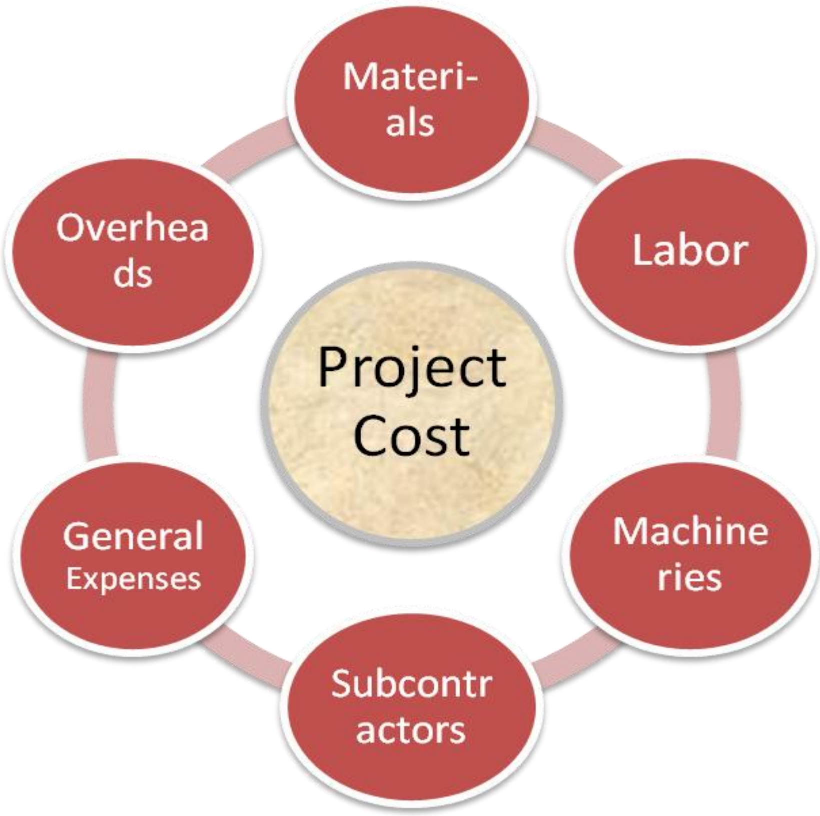


Figure 5.6: Main Cost categories used for the integrated system (Source: Author's proposal)

The PIS analysis continues with Figure 5.6 which explains very briefly all the cost categories, or most of them, that have been used to develop the integrated cost management system.

Materials: The materials category is a very broad category because it involves a long list in any project. It starts from concrete material and possibly ends with cables, or membranes, or any other small material needed in a project. Materials have been sub-categorized as explained previously, but since it is not possible to plan all project materials needed in the planning or estimation stage, there is always an option to make new entries throughout the project life cycle. The materials environment information system is mainly related to suppliers and contracts. Special care is given to establishing dates and delivery procedures, together with contract policies.

Labour: Labour is a very sensitive category, which needs to be categorized and set up before starting the entries in the control or estimation stage. Each sub-category of the staff or labour has its own characteristics, which are needed to be taken into consideration when this category is set up. Labour is hourly or daily rated, operators and drivers are rated on a monthly basis and engineers on both a monthly and annual basis. Therefore, this database includes various costs which are considered differently within activities costing. Engineers, quantity surveyors and other specializations are involved in the whole project or a package of the project, whereas labour is used only for specific activities.

Plants/ Machinery: This section has its own database and its own rates. The rates include among others, working hours, idle hours, fuel rating, insurance etc. Each plant has its own unique ID number and can be assigned to any activity for cost estimation. In the proposed integrated system, the plant environment allows for cost control in any maintenance activity in plans, which are assigned in the plant and not in overhead expenses.

Subcontractors: Subcontractor category is related mostly to contracts. Each company uses specific contracts with each subcontractor, or revises the old ones. In any case, this database in part consists of already used contracts, or new contracts for the specific project. Subcontractors' contracts are assigned to the nature of the work or activity, and there is always a policy to assign costs directly when it is needed.

Overheads/general expenses: These costs are used in a separate environment just because managers need to control them apart from the direct cost of each project. Since they are not assigned to the production costs, they are used to measure the expenses needed to execute production costs. Sometimes they are used as a percentage of the whole production costs, sometimes as several companies' accounts, and that depends on the companies' operation process.

The PIS environment is a dynamic Information System in which any member of the project will save information in a specific structure according to the needs of the project. The proposed integrated cost management system will be fully applicable to most small, medium and large contractors and clients, irrespective of the kind of projects undertaken.

The PIS that has been adopted to support the integrated cost management system, and is described in this chapter, produces a dynamic and easily adopted system which focuses on cost management, but also becomes a part of the Information System of the whole company's operation, rather than a separate system.

The submission of this research is expected to achieve a step closer to Automation in Construction, no matter the needs of any complex project, and also to become a useful tool for decision making throughout a project life cycle.

5.5 PROPOSED ICMS-P

5.5.1 PREAMBLE

The initial proposal was based on the need to develop a system that would be a decision-making tool both for contractors and clients. This need led this research to be divided into a product- based cost management system and a resource- based cost management system.

The product- based cost management system simulates the finished project rather than the process of project construction. It therefore must be based on data relating to finished work. The client needs to cover the elemental aspects of the project less than the resource aspects. This research uses elemental cost analysis as a technique of the product- based cost model.

On the other hand, a contractor's needs within the construction process are concerned with the management of materials, labour, sub-contractors, plants and overhead expenses. Therefore, the proposed cost management system is also designed to cover the full control of these five variables in the construction process.

The planner or cost controller will have the opportunity to decide which method is appropriate according to the period of estimation and the project needs.

Today, estimation and control methods meet both clients' and contractors' needs. This system combines the product- based and resource-based cost management systems and provides information to cost estimators and cost controllers according to the project's needs. The basic idea of the proposed system is to use the activity information from estimation to control process automatically.

To fill the gap between the elemental cost planning and resource-based cost planning, every major element of the types of construction is analysed in terms of resources needed. A combination of estimation techniques is used to transfer data from the elemental analysis to the resource-based analysis. It is very useful for any planner or manager to have reliable cost reports, even if estimation analysis differs from cost control data.

5.5.2 SYSTEM DEVELOPMENT

The current cost management system has been developed for two main reasons: first, to define the cost of any project activity or project package; second, to verify the truth of this simulation of cost.

When we discuss cost systems, mainly we refer to the simulation of reality in such a way that we then can control it when the reality occurs. Thus, we succeed in developing a cost archive which approaches reality, and may control all the economic variables that are produced from cost control.

The Integrated Cost Management System that is proposed relies on specific functionalities.

Initially, the framework of the requirements and characteristics of the system is explained. Following this, there is an in-depth analysis of the type of framework that has been proposed for research purposes. The system development uses an internal mechanism which is defined as The Internal Mechanism of Integrated Cost Management System, and it is analyzed later in this section of the chapter.

Continuing with this section, the integrated system mechanism in the project life cycle is provided. This Integrated mechanism supports the framework requirements and it is the key for the System Development Architecture, which is described later in a section of the chapter. The System Architecture is a flow diagram which explains in total the structure of the Integrated System, the steps, and how it works. The System Architecture is described later in this section of the chapter.

5.5.3 FRAMEWORK REQUIREMENTS AND CHARACTERISTICS OF THE SYSTEM

The proposed cost management system has the following flexible structure that can be adjusted according to the type of project, the contract and the final form as designated by the client or contractor. (This framework is not strict and it might be revised accordingly).

It consists of three main areas/packages in its final form, but in this research analysis of the cost management system framework it is introduced as the initial stage of design of resources or design of elements, which is the primary sub-stage of the main cost estimation stage. The other two packages of the system are the cost budgeting and cost control packages.

The structure of each package or stage is introduced with inputs, then the tools and techniques used are defined and finally the output of each specific stage as information to proceed in following stages is given.

The following Figure 5.7 shows each stage of the cost management within the project life cycle. The methods and tools, the inputs and the outcomes provided in this section are based on the information related to the cost estimation and cost control techniques described in chapters two and three.

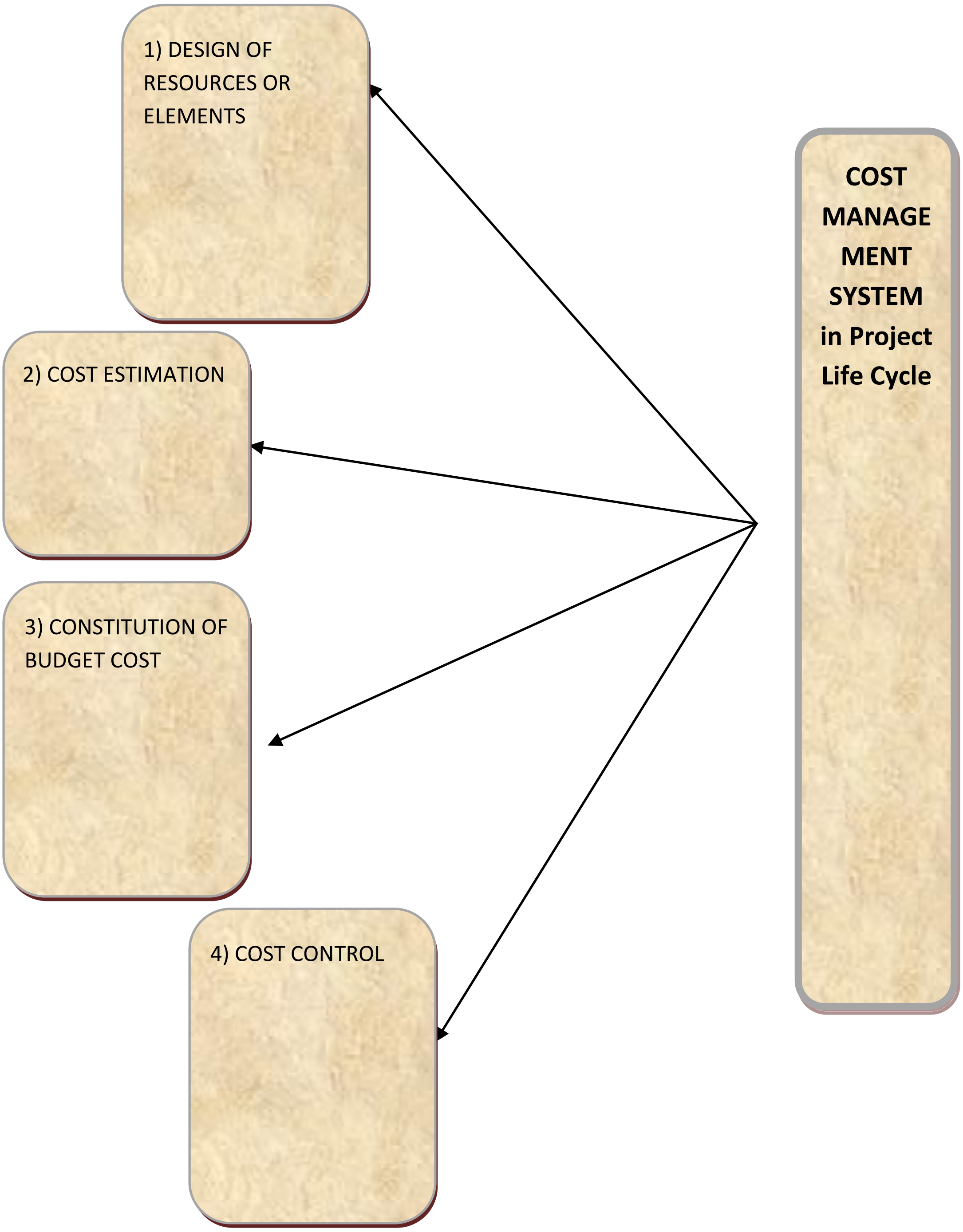


Figure 5.7: Cost management system framework packages or stages (Source: Author's proposal)

1) DESIGN OF RESOURCES OR ELEMENTS

Inputs

WBS

Activities ID/Elements ID

Historical data

Project Scope Statement

Description of elements or resources

Organizing methodology/Organizational Process Assets

Estimation of duration of activities

Enterprise Environmental Factors

Techniques and tools (Processing)

Estimation of experienced managers

Assessment of alternative solutions

Project management software

Outputs

Resources demands

Project Management Plan

Early Activity durations

Risks and threats

Figure 5.8: Stage one DESIGN OF RESOURCES OR ELEMENTS (Source: Author's proposal)

WBS: In this initial stage, the Work Breakdown Structure is the most important input resource design and other elements (Figure 5.8). This is because it is the first approach to building a structure in levels with the basic elements that are available at that stage. It could be argued that the initial WBS is a guide to how to build in the rest of the details of the project information.

Activities/Elements ID: It is vital at this stage to determine the ID code of each element or activity used. ID supports any unique reference to each activity, and is used to determine a code system familiar to any of the staff involved in the system process.

Project Scope Statement: Members of the system that are involved should define the right documentation of the total Project Scope of works: what elements and what activities are defined in the project, and a detailed analysis of works and structures that are to be constructed.

Historical Data: Since the project scope statement is set, it is important to assess and evaluate all the information that the organization has in its archives and might be useful for future reference. Rates, prices, problems in construction etc., are some of the information frequently asked for.

Description of elements or resources: The description of elements or resources is the first step to describing what is to be constructed and with what resources. It is not a final approach but this description of dimensions, locations, concrete and reinforcement issues, etc. supports the decision making to proceed with the cost estimating process.

Organizing methodology/Organizational Process Assets: Each organization or company usually has its own processes to deliver projects. This methodology needs no setup and is adjusted to a project's needs by that stage, so any conflict of procedures within the company will be avoided if the policy is set up in this initial stage.

Estimation of duration of activities: A very important aspect in the framework is the estimation of an activity's duration. It is a prerequisite to define those durations as a starting base without using so much detail. This approach defines for managers the answer to the question that often emerges: "where are the things going to?".

Enterprise Environmental Factors: All environmental factors are important, but in this stage a minimum approach to how to solve all the environmental issues that may emerge during the construction of the project must be prepared. That minimum is the list of environmental issues and suggestions and solutions to those actions that will solve the potential problems.

Estimation of experienced managers: In these early stages, the experienced project managers have the best picture and knowledge to deliver the outputs needed for the cost management system. It could be argued that their contribution is very important at that stage as it helps them to proceed with a valid project management plan.

Assessment of alternative solutions: the process of defining alternative solutions is a dynamic assessment of the project managers and their solutions are used in the documentation of the project management plan as an output.
Project management software: Software in project management is usually used to analyze all the information mentioned before and could be kept as a record for future use. It is strongly recommended to use project management software; otherwise mistakes will be transferred to the following stages.

Resource demands: One of the final outputs in this first stage of the cost management system is the catalogue and a document of the resources that are demanded for the project. No one is expected to have an analytical and detailed catalogue of all the resources needed, but a guide to use for future use is helpful.
Project Management Plan: The project management plan consists of resources, durations, alternative solutions, environmental issues; policies in processing within the company, staff needs. At the same time, this document should describe all the actions need to be taken based on that information.
Early Activity durations: An outstanding clear catalogue of all activities that could be described at that stage with non-fixed durations and comments providing extra information regarding the possible effect that this duration may have in the future.
Risks and threats: It is the first time the term RISK is defined in this framework. Risks and threats are so important to project managers because they help them to take decisions accordingly. Hence, this output is the first effort to define all the potential risks of the activities defined in the scope of works, without any evaluation or assessment.

2) Cost estimation

Inputs

WBS dictionary

Resources demands

Estimation of duration of activities

Historical data

Risk description

Initial costs and categories of costing

Variations and claims methodology

Project management Plan

- Schedule Management Plan
- Staffing management Plan
- Risk Register

Techniques and tools (Processing)

Estimation techniques (parametric, analogous, bottom-up, probabilistic methods)

- Analogous Estimating
- Determine Resource Cost Rates
- Bottom up estimating
- Parametric estimating
- Vendor Bid analysis
- Reserve analysis
- Cost of Quality

Computer tools

Alternative cost estimation techniques or combination of the four mentioned

Outputs

Activity Cost estimates

Activity Cost estimates details

Supportive project information

Requested Changes

Cost management plan of action (updates)

Figure 5.9: Stage two Cost estimation-examples (Source: Author's proposal)

WBS dictionary: The second stage, which is the estimation stage, needs specific inputs to run through, and most of those inputs are found in stage one Figure 5.9. The WBS dictionary is an important document to help define the estimation structure. By that stage, estimates are being prepared more analytically, to match the project's criteria and needs.

Resources demands: The same applies to resources demands, which in this stage are being defined more analytical and become a document with valid information, hence they must be prepared with great care. That means that all the resources that could not be predicted in previous stage, this is the right time to make a full inventory.

Estimation of duration of activities: An exact copy is the duration of activities. At that stage, full documentation must be prepared with most of the factors affecting the time of each activity measured and recorded or assigned to the activity.

Historical data: There is a continuity in historical data emerging, since now the analysis of each activity is clearer and more related information regarding the activity is available, and possibly the data can be revised and matched to the project activities.

Risk description: risks are being categorized and evaluated according to their effect on the project. Some of them may be rejected or recorded and recalled in later stages. The rest of the risk list will be used in the project management plan.

Initial costs and categories of costing: it could be argued that costs in that stage are used extensively. From historical data, from experience or from resource demands, this is the stage to define the costs. Costs should be categorized according to the scope of works and to the nature of each activity. The documentation that is needed to be prepared involves lists with cost rates or fixed costs from past activities, and records and any other cost information that supports the estimating by that stage.

Variations and claims methodology: Any policy and structure of variations and claims is needed to be defined by that stage, based on risks and potential threats to the project, and economic and political issues during the period of construction.

Project management Plan: Final input at that stage is the Project management plan which is found in stage one as an output. This involves:

Schedule Management Plan: A more complete schedule plan which indicates durations and actions to be taken to meet those durations.

Staffing Management Plan: Usually in the second stage, it must be defined as a complete plan of staff that will be used, costed, evaluated and made a part of the cost estimation document.

Risk Register: Risk in a project management plan involves the acceptance of potential risks and a first approach to managing them, i.e., evaluating them and

assessing them in such a way that they can become part of the cost estimation. That means risks need to be transformed to a cost measurement. Within this input and documentation, all risks must be categorized and must be described as an initial policy if those risks are to be taken, minimized or transferred in a future process within the project life cycle. Any policy of risks will have its own weight in cost estimation (taken risk, full cost used in cost estimation, minimizing risk percentage of cost taken, transfer the risk, means the cost is not included in cost estimation and is used for variations or claims) and this must be shown and described clearly.
Estimation techniques: Parametric, analogous, bottom-up, probabilistic methods.

Analogous Estimating: A closed project can help at that stage to recover any activity cost information and apply it to the current project. This top down technique, that could be one of the methods used in that stage, is a less costly method, but is important to be aware that is not as accurate as other techniques.
Determine Resource Cost Rates: In this method, by that stage all the resource cost rates are calculated and defined and can be assigned to the cost of activity
Bottom up estimating: Bottom-up estimating estimates the individual cost of items for each of the activities needed within the project. By adding the individual project costs together, the overall cost for the project can be estimated. It is strongly recommended to use the ABC method as a bottom up one.
Parametric estimating: The parametric cost estimate uses cost estimation relationships and mathematical algorithms to establish final estimates. Each method is a valid choice according to the nature of the project, and must be decided by that stage.

Cost of Quality: A very important measurement and tool in the cost estimation stage is to define the quality process and cost it. Quality is always an important and daily issue in construction work, therefore a careful design for how to manage this quality and how much it will cost is needed so it can be included in the cost estimation final output. Costing quality relates to the specifications of the contract, the agreements and the common practice of engineering and, of course, legal legislation. Any variance in the above factors affecting quality is measurable and categorized in the cost management system as an issue for evaluation and assessment. The issue of variance in specifications also affects the quality assessed by the time the system reveals that the variance affects the project delivery.

Computer tools: All the mentioned techniques and cost estimation methods need an appropriate software or package of software to make them work and run. The tools to apply those methods must be decided by that stage, and they must be used to deliver the cost estimation final documentation.

Activity Cost estimates: After the processing of various tools mentioned above, the main output of the cost estimation stage is the “Cost Estimation” final report which will be the basis of later budgeting. By that stage, it will be obvious if the structure that was defined in stage one has been followed, or if any feedback or revision must be prepared. In any case, even if it is the final document, or a revision of the final, it is the basis to prepare the final budget of the project.

Activity Cost estimates details: Together with the cost estimation document, it is a report of analytical cost estimates of each activity, with details of methodology used and assumptions made.

Supportive project information: All supportive information is prepared as output at that stage, and kept as a record for further use. This is mainly design assumptions, not detailed designs, and poor Work Method Statements, which are not easy to prepare in the cost estimation stage.

3) Constitution of budget cost

<u>Inputs</u>

Project Cost Statement
Work Breakdown Structure
WBS Dictionary
Activity Cost estimates
Activity cost estimates detail
Project Schedule-Time Schedule
Resource Calendars
Contract
Variations and claims methodology detail
Cost Management Plan
Risk analysis/plan of risk allocation

<u>Techniques and tools (Processing)</u>

Cost Aggregation
Reserve analysis
Parametric Estimating
Computer tools and software
Constitution of budget cost with appropriate computer software, Primavera, MS Project, SAP, Prince, Excel, MS Access, etc.
Constitution of Budget, within PIS
ERP/EPP cost constitution

<u>Outputs</u>

Cost baseline
Project Funding Requirements
Cost Management Plan
Requested Changes

Figure 5.10: Stage Three Constitution of budget cost (Source: Author's proposal)

Figure 5.10 describes the third stage of the framework of the system in which the budget cost is formed.

Project Cost Statement: The previous stage cost estimation report is used now as a baseline to prepare the budget of the project. This is called the Project Cost Statement.

Work Breakdown Structure: The work breakdown structure that has been prepared in previous stages now is expanded (still based on the same ID codes) and is prepared more analytically in its final form and structure. The WBS is the key factor for the whole integration process.

WBS Dictionary: This dictionary is the documentation of what is included in the WBS, how it is structured and what methodology is followed. Special notice is given to levels of detail and hierarchy levels, where the project manager or project director must be aware of the future control of the cost in construction stage.

Activity Cost estimates: The main output of the cost estimation stage, the “Cost Estimation” final report, is used now as an input for the current budgeting stage. This input is investigated for extra revisions made in the meantime. Hence, all revisions re-arrange activity cost estimates if needed.

Activity cost estimates detail: As an input, the analytical details define any information regarding how the cost is affecting the activity, and is used as an input to proceed to the budgeting process.

Project Schedule-Time Schedule: This is the stage of the final baseline project schedule. The project schedule is being prepared prior to the budget documentation and is used to determine costs extended on time. Hence, this is one of the most valuable inputs in that stage.

Resource Calendars: The resource calendars structure is structured and used to prepare the budget. Resource calendars need to focus on WBS structure, and become important tools in the integration process. Calendar includes, among others, the information occurring on construction sites on a real time basis, and is the only valid record on construction sites.

Contract: All suppliers’ and subcontractors’ contracts are assessed and used at this stage, and involve not only the subcontractors’ or supplier’s rates, but also valuable information regarding the payments and procurement.

Variations and claims methodology detail: Since the other inputs are ready to process, it is important to set up the structure of the claims and variations within the project. This happens in this stage because most of information regarding activities’ cost and project costs and contract responsibilities and risks have already been defined. Hence, any extension taking place from now on that is not among the contractors' or client's risks the policy to control it has to be categorised and prepared.

Cost Management Plan: The cost management plan is now ready to use. It includes all the necessary information for budgeting, and all connections with previous stages, all the control stages already having been connected and integrated. This input is used to define the environment where the Project management will be involved and takes into account any decision taken from this stage up to completion of the construction stage.

Risk analysis/plan of risk allocation: Most of documentation of risk analysis is used for claims and variations. The whole documentation is now ready for usage to budget the project. According to decisions taken, to minimize and transfer the risk, the cost will be used in budget or not accordingly.

Cost Aggregation: Is the process where the cost is calculated and prepared.

Reserve analysis: Reserve analysis actually refers to a specific technique that is often implemented by the project management team and/or the project management team leader or leaders for the purposes of helping to better maintain and manage the projects that they may have under their guise at that respective time. Specifically speaking, the technique of reserve analysis is an analytical technique that is used for the purposes of making a complete and thorough determination of the entirety of the specific and exact features and/or, in many cases, relationships of all of the individual project related components that currently exist as part of the previously determined project management plan. The purpose of the execution and implementation of a reserve analysis is the establishment of an estimated reserve that can be used for the purposes of establishing a schedule duration, any and all estimated costs, the budget, as well as the complete funds assigned or allocated to the project.

Parametric Estimating: The same process as used at the cost estimation stage is also used budgeting the final cost.

Computer tools and software: The tools and software which were chosen to manage the cost are used in this stage to prepare the budget documentation according to the inputs described.

Constitution of budget cost with appropriate computer software, Primavera, MS Project, SAP, Prince, Excel, MS Access. No matter what the appropriate computer software is, the budget must be constituted through one or a combination of that software.

Constitution of Budget, within PIS: The budget should be involved within the PIS as described previously in this chapter. The PIS environment supports the preparation of the budget and is the environment where budgets can be checked and corrected if needed.

ERP/EPP cost constitution: Part of PIS is the ERP or EPP system where the budget is shown. The right choice of ERP as a cost management tool will affect the reporting system in the final stage.

Cost baseline: This refers to the BUDGET baseline, which is the basis for any future comparison with real cost or totally the control management. The cost baseline is a full documentation in various forms depending on the nature of the project or the priorities that any project manager or project director sets to check and control.

Project Funding Requirements: When the budget has been set up and the complete documentation of the budget is already fixed, it has also to be extracted and another budget, which is referred to as the incomes of the project, prepared on the basis that the cost budget is being fixed. Usually, the monthly basis is adequate, but possibly two weeks' control of incomes and costs or three months' maximum depending on the installments of the project could be used.

Cost Management Plan: Since the budget is fixed now, the cost management plan is already set, involving all the parameters of the project that the management board needs to know. In the case of the system development, the cost management plan is a very important document or report that enables managers to control the cost and make feedback at any stage of the project's delivery.

Requested Changes: All requested changes have now been recorded, have been costed and actions taken, depending on the progress of the project. Usually these changes are to do with contract prices, increase of petrol value, copper and reinforcement value and design changes (e.g., changing a type L wall to single or double pile).

Mapping out the policy of cost management: The policy of cost management comes after the final budget and is prepared directly, at least the framework is, by the project manager or project director, mainly because it is related to his decision making policy in construction period.

Set up PIS methodology: PIS methodology at this stage mainly refers to the connection with the reporting system and how budgets and real costs will be presented.

Even if this actually occurred in the control stage Figure 5.11, the initial preparation is analyzed in the current stage.

4) Cost Control

<u>Inputs</u>

Cost baseline
Project Funding Requirements
Performance Reports
Work Performance information
Approved Change Requests
Project Management Plan
Mapping out the policy of cost management
Project progress reports
Claims for revision
Strategic Plan of cost management

<u>Techniques and tools (Processing)</u>

Cost change Control System
Performance Measurement Analysis
Forecasting
Project Performance Reviews
Project Management Software
Variance Management
Computer tools and software
Earned value analysis
System of cost variation
ERP/EPP cost control
PIS process

<u>Outputs</u>

Cost Estimates (updates)
Cost baseline (updates)
Performance Measurements
Forecasted Completion
Requested Changes
Recommended Corrective actions
Organizational Process assets (updates)
Project Management Plan (updates)
Review of cost estimation
Modification of budget
Corrective activities
Payment methods
Project construction performance
Etc….

Figure 5.11: Stage four Cost Control-examples (Source: Author's proposal)

Cost baseline: The Cost Baseline at the control stage is mainly used to compare actual and budget costs. It is a continuous process between values of estimates and new entries within the system. This comparison is always supported by reports and the reporting system.

Project Funding Requirements: Since the setup of the incomes has been identified in the budgeting stage, in the control stage these values are recalled automatically as a reference based on actual incomes, in projection with budgeting incomes. The period of control for those values varies from two weeks to three or six months, according to the project's needs.

Performance Reports: The most important input in the control stage is related to performance reports. What reports should be used, what is the purpose and what numbers can finally be extracted to support the project's manager decisions. This input may include various structures and forms of how these values will be presented, and possibly recalculate other results of the project.

Work Performance information. This input is the conclusion of the previous input, which defines the information decided to be delivered within the project, and is supported by full documentation.

Approved Change Requests: The changes which were described as an output in the budgeting stage have been recorded, evaluated and assessed. At this stage, the approval throughout the control stage is included. The approval or non-approval will provide valuable information for further actions by staff or the project manager.

Project Management Plan: The project management plan in this control stage, is mainly related to decisions which have already been taken and decision policies for the future. Also included is a guide to how this information will be presented to the project manager along with potential solutions, suggestions and their effect.

Mapping out the policy of cost management: The policy of cost management comes after the final budget and is prepared directly, at least the framework is, by the project manager or project director, mainly because it is related mostly to his decision-making policy in the construction period.

Project progress reports: The reports of the system are mainly the environment of a specific list of reports used to control and manage. This list is defined as a core list of the reporting system and the project manager must be aware of the information derived from those reports.

Claims for revision: In the control stage, any information on variations and claims is being recorded and categorised for comparison with the budgeting stage claims management. In any case, claims and variations demand a clear decision from the project manager if the actual cost of variations and claims are to be included in the actual cost, or kept as a record for further use.

Strategic Plan of Cost Management: The cost management strategic plan is mainly related to the ability to control and manage cost in any stage of the project delivery, even if the present time is the control stage period. Managers need to manage the previous stages, to correct the procedures or correct any omissions or mistakes occurred in the process.

Cost Change Control System: The cost change control system is mainly the mechanism of comparing the actual and budgeting costs.

Performance Measurement Analysis: Performance measurement analysis relates mainly to calculations of the values and the entries of the system.

Forecasting: special mathematical equations have been used to provide forecasting results.

Project Performance Reviews: Reviews of the project performance have been considered to secure the verifications and validity of those results.

Project Management Software: Project management software is a combination of software which is used to apply the system and provide reports.

Variance Management/ System of cost variation: Claims and variance management is a process used to determine the exceeding cost and excess the time.

Computer tools and software

Earned value analysis: EVA is a special methodology which is used in cost control with sufficient results. Extensive reference has been made in this chapter to EVA analysis.

ERP/EPP cost control. ERP and EPP are all the functions related to the system and the software to provide the information in reliable forms.

PIS process: This is the process of the PI system and mostly is related to the staff involved and their responsibilities within the system.

Cost Estimates (updates): Cost estimation forms in the updated version and detail analysis in full comparison with actual cost.

Cost baseline (updates): Baseline forms which are used in updating the schedule or the cost. Mainly these are forms and are explained analytically in this chapter.

Performance Measurements: Mainly these are the results and indices and percentages related to the progress of the project.

Forecasted Completion: Forecasted indices are found in many forms and are very important as an output result.

Requested Changes

Recommended Corrective actions: The system can provide suggestions for corrective actions and warning the managers to take further action. This is a very important document at that stage.

Organizational Process assets (updates): Through the process of the cost management, it is necessary to ensure that all procedures and processes inside the organization or the company have been followed. This report is very important for quality management.

Project Management Plan (updates): All the updates related to the project management plan. This is a report, but it can also be used as an input with new updates (Feedback procedure).

Review of cost estimation: Again, this is a feedback procedure to ensure estimations were adequate or need to be revised (mainly for future projects).

Modification of budget: Modifying the budget is mainly related to the review of the budget mentioned above.

Corrective activities: This documentation mainly relates to the recommended corrective actions and activities which first have been approved or rejected by project managers.

Payment methods: Payment methods are related to the policy of the company to provide invoices when the cost has been approved. It compares the production cost with payments.

Project construction performance: It is one of the main reports which provide information of schedules and costs and a combination of those two. It gives a clear picture to the project manager if the project is under or over budget, and behind schedule or not.

5.5.4 EXAMPLE OF FUNDAMENTAL CHARACTERISTICS OF COST MANAGEMENT SYSTEM

In this section, an example of a project activity is analysed in terms of resources. This analysis uses a generic algorithm which calculates the total project cost per cost estimation method chosen, and the various project features (Long et al., 2009).

The choice of which level of the hierarchical structure of WBS is preferable must be in cost control to meet our needs for this specific project. The more levels of cost control are aimed at, the more operating cost is needed to control the cost occurred (Gu et al., 2011).

Therefore, a wise policy is needed to achieve the optimum solution of detailed cost control and the high operating cost when controlling the budget. Furthermore, it has been proved that more time is needed to control multiple levels in project cost, and it is doubtful if any contractor could manage a detailed cost analysis for multiple projects at the same time.

The example describes an activity which is measurable in terms of cost. Having estimated the cost of the analytical (cost measurable) level, is it possible to calculate all the upper levels of the hierarchical structure, and therefore the whole project?

The initial way of approaching this is to estimate the cost of the minimum possible autonomous activity or element that is needed to produce a specific amount of work, as shown in the example. - considering an activity as an example which is autonomous in construction projects.

i.e. Slab concrete of first floor on a 6-storey building Table 5.2.

Table 5.2: Hierarchical cost level of activity (Source: Author's proposal)

LEVEL 1 PROJECT PACKAGE	LEVEL 2 STAGE	LEVEL 3 MEASURED ACTIVITY	LEVEL 4 COST BASIS ANALYTICAL LEVEL	ID CODE
CONCRETE WORKS				C
	SLABS			02
		CONCRETE SLAB 1ST FLOOR		01
			MATERIALS	01
			LABOUR	02
			PLANTS	03
			SUB CONTRACTORS	04
			OVERHEAD COSTS/OTHER COSTS	05

It is assumed that the project has cost level 0 and is at the upper level. The activity computer ID for labour works is described as C.02.01.02

The term of cost basis analytical level, which is the last measurable level that can be estimated, is defined above. To estimate the cost of this level, the measure of units need to be defined, as well. (Table 5.3)

Table 5.3: Units in cost levels (Source: Author's proposal)

Cost levels	Cost level ID code	Measure units	Measure units ID code
Concrete works	C	Percentage complete	PC
Slabs	C.02	Percentage complete	PC
Concrete slab 1st floor	C.02.01	Percentage complete	PC
Materials	C.02.01.01	Materials rates (i.e. Kg)	Kgr
Labour	C.02.01.02	Labour working rates (i.e. hours-HR)	HR
Plants	C.02.01.03	Plant working rates (i.e. hours-HR)	HR
Sub- contractors	C.02.01.04	Fixed price or price per unit (i.e. €/m3)	€/m3

Overhead expenses/other costs	C.02.01.05	Fixed cost (i.e. €)	€

In a hierarchical structure of a project it is necessary to describe not only the connection between the higher and lower levels, but also to describe how much of each activity is needed, in terms of measure units, to complete its package. (Table 5.4)

Table 5.4: Quantities measurement related to units (Source: Author's proposal)

LEVEL 1	**LEVEL 2**	**LEVEL 3**	**LEVEL 4**	**ID LEVEL CODE**	**MEASURE UNIT**	**PARTICIPATION FACTORS**
Concrete works				C	PC	1
	Slabs			C.02	PC	1
		Concrete slab 1st floor		C.02.01	PC	1
			Materials	C.02.01.01	Kg	X1
			Labour	C.02.01.02	HR	X2
			Plants	C.02.01.03	HR	X3
			Sub- contractors	C.02.01.04	€/m3	X4
			Overhead expenses/other costs	C.02.01.05	€	X5

X1, X2 ....X5 are the different quantities of the analytical level (the base level).

Continuing the process, the cost of any measure unit described is defined as the cost per unit. At this stage the cost per unit and per project cost level are defined. (Table 5.5)

Table 5.5: Cost per unit measurement (Source: Author's proposal)

LEVEL 4 **COST BASIS** **ANALYTICAL LEVEL**	**ID LEVEL CODE**	**MEASURE UNIT**	**Cost per unit**
Materials	C.02.01.01	Kg	C1
Labour	C.02.01.02	HR	C2

Plants	C.02.01.03	HR	C3
Sub- contractors	C.02.01.04	€/m3	C4
Overhead expenses/other costs	C.02.01.05	€	C5

The cost defined in table 5.5 is mainly the budget cost per cost level in the hierarchical structure of cost estimating. Therefore, it is possible to estimate the final project cost and the cost of all levels, as well.

The calculation that is used to estimate the project cost processes from the basic level up to the top level is presented in Table 5.6. The cost of an upper level is the summation of the lower levels multiplied by the participation factors. (Table 5.6)

Table 5.6: Hierarchical cost calculation of measured activity (Source: Author's proposal)

LEVEL 3 MEASURED ACTIVITY	**LEVEL 4 COST BASIS ANALYTICAL LEVEL**	**ID LEVEL CODE**	**Cost**
		C	1
		C.02	1
Concrete slab 1st floor		**C.02.01**	**(X1*C1)+(X2*C2)+(X3*C3)+(X4*C4)+(X5*C5)**
	Materials	C.02.01.01	X1*C1
	Labour	C.02.01.02	X2*C2
	Plants	C.02.01.03	X3*C3
	Sub- contractors	C.02.01.04	X4*C4
	Overhead expenses/other costs	C.02.01.05	X5*C5

5.5.5 Internal Mechanism of the Proposed System

From the literature, observation of the systems and empirical work in this research, a system is proposed that follows the common practice of providing inputs, then processing the inputs and finally taking outputs as results.

The research methodology of the proposed system relies on following the time process diagram for its implementation.

These inputs are used in a process by using tools and techniques which differ in various stages and which lead to specific outputs at each specific stage.

Very simply, this is called an internal mechanism of the system, and it is clearly shown in the following figure:

- Inputs
- Processes and Tools
- Outputs

Figure 5.12: Internal Mechanism of Integrated Cost Management System (Source: Author's proposal)

Figure 5.12 above shows the methodology of the internal mechanism which has been adapted to create an integrated cost management system.

5.5.6 Integrated Mechanism of the Proposed System

Before proceeding to discuss how the system has been developed and what the architecture of the proposed cost management system is, it must be stated that in the integration process each output becomes an input for the next stage and so on, with feedback procedures in all stages of development in the project life cycle. This process allows the users and managers to get involved at any stage of the system, and take corrective action on the process or the results.

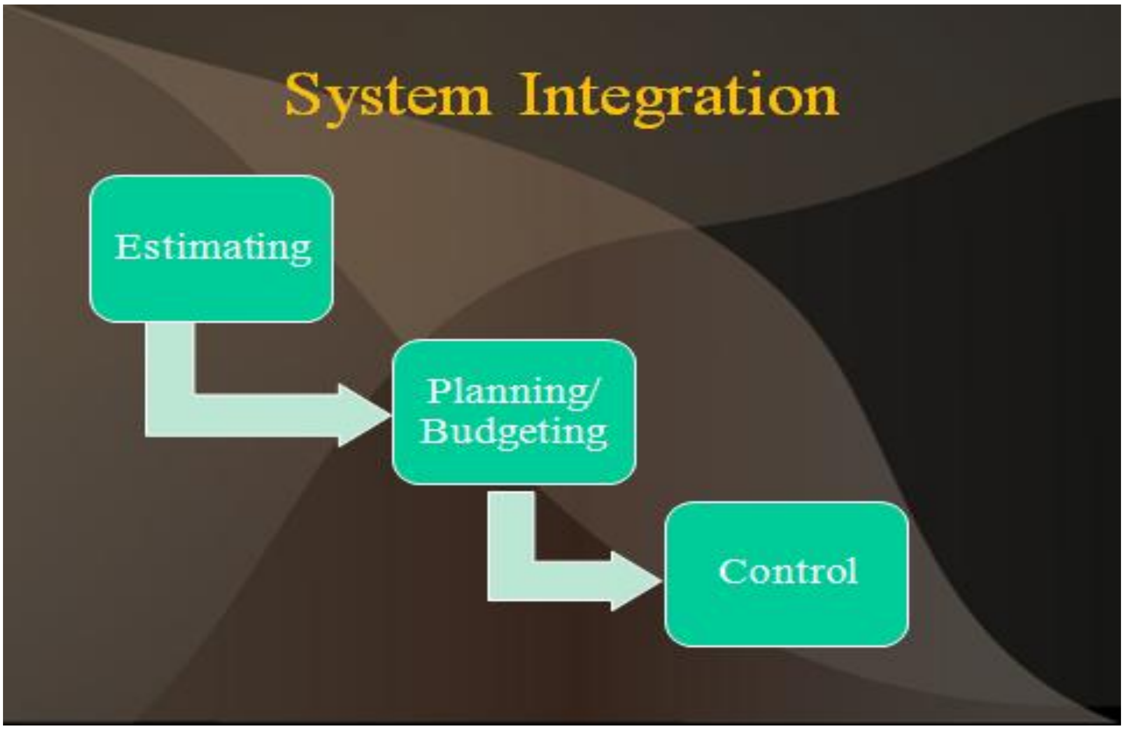


Figure 5.13: Integrated mechanism system in project life cycle. (Source: Author's proposal)

Within the Integration System, all information from estimation stage to planning stage, and hence to control stage have been integrated, and therefore the whole process is only a single process since integration is taking place in all stages of the project.

The integrated mechanism is used in all the stages and all the requirements and characteristics of the proposed framework.

5.5.7 System Architecture: Design and stages of the System Development

The integrated cost management system for project delivery that is proposed has been designed to be completed in three main stages: the model analysis as stage one, the model development as stage two and the model parameterization and application as stage three. All these stages are described in a continuous, dynamic process with feedbacks and specific inputs and outputs. The system design process is presented in the following flow diagram (Figure 5.12) explaining all the steps of the development.

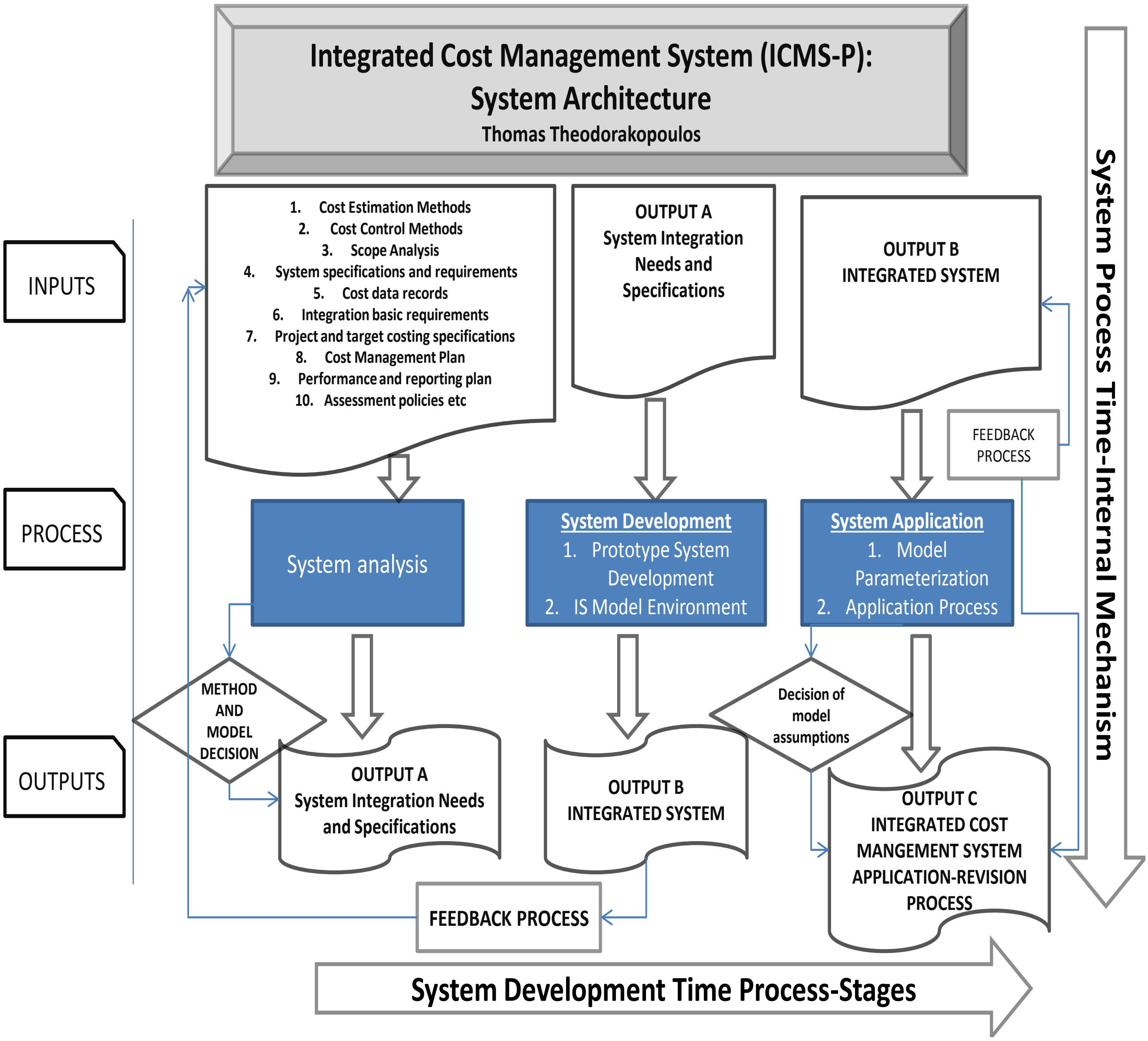


Figure 5.14: System Architecture: Design and stages of the System Development (Source: Author's proposal)

The proposed integrated cost management system has been developed based on two axes.

The horizontal axis represents the time process to design and develop all the stages of the system. The whole process has been developed in three stages:

A) The system analysis stage, by defining the basic parameters to set up the cost management system.

B) The System Framework prototype within an IS environment, which is the basis of the application of the system development.

C) The parameterization stage of the system, which defines the uniqueness of the project or construction, making the system applicable through an application model development.

The vertical axis represents the system process time which describes the interim mechanism of the system and how it processes at various stages. These stages include the inputs, the outputs and the processing variables in each stage of system development. The key factor in this system is the fact that the outputs of each stage become the inputs in the next one, and the whole process is a continuous flow of information, with feedback at any step.

The first stage of the development IS is the system analysis. This stage includes all the important inputs of the project related to cost and more. This is empirical work based on techniques and methods described in the literature. These processes provide, at any stage, all the necessary needs to integrate the system, i.e., all the needs and specifications required before proceeding to the next, second stage of developing and integrating the system. The current stage of the system relates to the cost management framework that has been proposed, and in all stages of cost management procedure exposed to cost control.

From the research, it was found that the first stage is vital, and without these specifications, these outputs, the system will not be integrated.

The second stage is the stage where an integrated system and the application environment becomes output. How does this succeed? Using all specifications as inputs from the first stage, and with the techniques and through the integration mechanism, finally an integrated system is accomplished in stage three with the completion of the application model of the system.

5.6 SYSTEM INTEGRATION NEEDS AND SPECIFICATIONS: STAGE ONE

Stage One of the ICMS-P is System Analysis, from which there the needs and specifications of the system are derived in order to proceed to stage two. To accomplish the first stage, it is necessary to establish all these factors and requirements as inputs to be used in the integration process, later in stage two. These requirements are provided in the framework of cost management system requirements, without excluding the opportunity for a client or a contractor to revise or enrich this framework.

The input information at stage one could be derived from the framework inputs, tools and outcomes. It is important at this stage not only to establish the cost estimation procedures, but also the cost control policy requirements so that these can be integrated in the next stage of the ICMS-P development procedure.

Depending on which stage we develop the system to, we have to choose the appropriate estimation methods to use. As described in the framework of requirements, there is a variety of methods and techniques available and the nature of the projects will define the optimum choice of methods. The same procedure is followed to establish the cost control methods. The clients' and contractors' needs will define the control methods which will be used among measurement policies, reporting systems and correction plans and assessments of variances of scheduling and planning.

In this section of the chapter an approach is described to the stage one system analysis, which is almost unlimited in information that could be used, and the methods to follow.

The system analysis stage is the most important since it establishes all the parameters to set up the system properly to be functional. The purpose of system analysis is to identify as an output all the integrated parameters needed to establish a complete integrated system in stage two.

As described above, it is important to identify the correct cost estimation methods that are about to be used. Analogous estimation, parameter estimation, bottom up estimation and top down are some of methods that could be used. The estimation methods provide all the current information of the project and data that will be used to prepare the framework.

Together with the estimation methods, the cost control methods, with an emphasis in Earned Value Analysis (EVA) which covers most of the project needs with no exception are also described in this stage.

The hierarchical process followed in the example of concreting the slab automatically bears most of the integrated needs that should be categorized and used to develop the system framework and development.

Regarding the importance of this first stage, the difficulty of developing a system if no specifications of the system found should be mentioned.

Taking this example, even though it is just a simple example to explain the process and not the only way to present it, clearly most integrated specifications have been included.

All four levels of activity described in the slab example have a unique ID coding system: CONCRETE SLAB 1ST FLOOR ⇒ C.02.01

COST BASIS ANALYTICAL LEVEL: In this case five main cost basis categories are described and one of them is the materials ⇒ 01

Hence, the complete ID code for the slab referred to materials is: C.02.01.01

Apart from the ID coding system, special attention is given to the unit system. To avoid any mistakes of how units match the activities, the unit system is integrated and followed up in the whole process to the final control stage.

The materials, i.e., reinforcement units, are defined in Kg and their cost is related to this unit. Even if the material cost or the subcontractor cost related to reinforcement or labor cost related to reinforcement is calculated, the result is always recorded in Kilograms.

An example of stage one requirements and system analysis procedures of some main activities and structures, and how this coding system can be developed for a real project scheme is given below. Table 5.7 refers to the bridge construction, which will be used as a case study in the next chapter. Table 5.8 describes the underpasses analysis, which will also be presented as a case study in the next chapter. Table 5.9 provides an example of the system analysis of a portal construction in a tunnel construction based on a real project scheme. To establish this analysis, much research and empirical work has been conducted, which includes defining the activity tasks, the WBS analysis, compiling the historical data to proceed in this hierarchical description, design changes, estimation cost factors related to the uniqueness of the construction, and many more requirements that were needed to come to this result of system analysis.

It is vital to mention that basic integration requirements and techniques are already established in this stage because a common structure, which is described in stage two, is needed. Stage one becomes the architecture and the base proceeding to stage two.

The unique coding system that has been chosen provides the basis of the integration that enables us to develop all the aspects and requirements needed to manage all the stages of cost management.

TABLE 5.7 CODING SYSTEM A (Source: Author's proposal)

CODING SYSTEM-B11- BRIDGES					
AWXXX					
4XXX					
	25N		BK	ACTIVITY CODE	
	Bridges		B11	**AW3.04B.25N.B11**	
	Bridges		B11.1	**AW3.04B.25N.B11.1**	
	BRIDGE KRATHIS-RL	62+XXX	B11.1.07	**AW3.04B.25N.B11.1.07**	
	1. Demolition of Existing Structure		B11.1.07.01	**01**	**AW3.04B.25N.B11.1.07.**
	2. Excavation , Piles and Pilecap		B11.1.07.02	**02**	**AW3.04B.25N.B11.1.07.**
	3. Abutments and Piers		B11.1.07.03	**03**	**AW3.04B.25N.B11.1.07.**
	4. Deck Slab		B11.1.07.04	**04**	**AW3.04B.25N.B11.1.07.**
	5. Finishing Works (Deck Slab)		B11.1.07.05	**05**	**AW3.04B.25N.B11.1.07.**
	6. Retaining Walls and Approach Embankments		B11.1.07.06	**06**	**AW3.04B.25N.B11.1.07.**
	BRIDGE KRATHIS-LL	62+XXX	B11.1.08	**AW3.04B.25N.B11.1.08**	
	1. Demolition of Existing Structure		B11.1.08.01	**01**	**AW3.04B.25N.B11.1.08.**
	2. Excavation , Piles and Pilecap		B11.1.08.02	**02**	**AW3.04B.25N.B11.1.08.**
	3. Abutments and Piers		B11.1.08.03	**03**	**AW3.04B.25N.B11.1.08.**
	4. Deck Slab		B11.1.08.04	**04**	**AW3.04B.25N.B11.1.08.**
	5. Finishing Works (Deck Slab)		B11.1.08.05	**05**	**AW3.04B.25N.B11.1.08.**
	6. Retaining Walls and Approach Embankments		B11.1.08.06	**06**	**AW3.04B.25N.B11.1.08.**

TABLE 5.8 CODING SYSTEM B (Source: Author's proposal)

	CODING SYSTEM-**B11- BRIDGES**			
AWXXX				
4XXX				
			BK	**ACTIVITY CODE**
	Bridges		B11	
	2		B11	**AW3.04B.22N.B11**
	Bridges			
	Underpasses		B11.2	**AW3.04B.22N.B11.2**
	54+XXX	K2XXX	B11.2.01	**AW3.04B.22N.B11.2.01**
	1. Excavation and Piles		B11.2.01.01	**AW3.04B.22N.B11.2.0 1.01**
	2. Bottom Slab, Side Walls and Top Slab		B11.2.01.02	**AW3.04B.22N.B11.2.0 1.02**
	3. Retaining Structures (Entrance - Exit)		B11.2.01.03	**AW3.04B.22N.B11.2.0 1.03**
	4. Approach Slabs and Backfilling		B11.2.01.04	**AW3.04B.22N.B11.2.0 1.04**
	54+XXX	K2XXX	B11.2.02	**AW3.04B.22N.B11.2.02**
	1. Excavation and Piles		B11.2.02.01	**AW3.04B.22N.B11.2.0 2.01**
	2. Bottom Slab, Side Walls and Top Slab		B11.2.02.02	**AW3.04B.22N.B11.2.0 2.02**
	3. Retaining Structures (Entrance - Exit)		B11.2.02.03	**AW3.04B.22N.B11.2.0 2.03**
	4. Approach Slabs and Backfilling		B11.2.02.04	**AW3.04B.22N.B11.2.0 2.04**
	54+XXX	K2XXX	B11.2.03	**AW3.04B.22N.B11.2.03**
	1. Excavation and Piles		B11.2.03.01	**AW3.04B.22N.B11.2.0 3.01**
	2. Bottom Slab, Side Walls and Top Slab		B11.2.03.02	**AW3.04B.22N.B11.2.0 3.02**
	3. Retaining Structures (Entrance - Exit)		B11.2.03.03	**AW3.04B.22N.B11.2.0 3.03**
	4. Approach Slabs and Backfilling		B11.2.03.04	**AW3.04B.22N.B11.2.0 3.04**

TABLE 5.9 CODING SYSTEM C (Source: Author's proposal)

	CODING SYSTEM-**B12- TUNNELS**				
	AWXXX				
	XXXB				
				BK	ACTIVITY CODE
	TUNNELS			B12	
	3			B12	AW3.04B.23N.B12
	TUNNELS				
	Tunnel XXX (WEST PORTAL)	XXX%		B12.1.W	AW3.04B.23N.B12.1.W
	Cover and Cut				
	Excavation up to Elev. +XX.15, Piles Pilecap			B12.1.W.01	AW3.04B.23N.B12.1.W.01
	Excavation up to Elev. +XX.75, Concrete Cover slab Lean Concrete, Backfilling			B12.1.W.02	AW3.04B.23N.B12.1.W.02
	Excavation under the Cover Slab			B12.1.W.03	AW3.04B.23N.B12.1.W.03
	Open Excavation			B12.1.W.04	AW3.04B.23N.B12.1.W.04
	Cut & Cover				
	Excavation, Temporary Support			B12.1.W.05	AW3.04B.23N.B12.1.W.05
	Lean Concrete, Bottiom Slab, Side Walls, Top Slab			B12.1.W.06	AW3.04B.23N.B12.1.W.06
	Backfilling			B12.1.W.07	AW3.04B.23N.B12.1.W.07
	Underground works				
	Excavation Temporary support Phase 1			B12.1.W.08	AW3.04B.23N.B12.1.W.08
	Excavation Temporary support Phase 2			B12.1.W.09	AW3.04B.23N.B12.1.W.09
	Final Lining			B12.1.W.10	AW3.04B.23N.B12.1.W.10
	Tunnel finishing Works			B12.1.W.11	AW3.04B.23N.B12.1.W.11
	Tunnel XXX (EAST PORTAL)	XXX%		B12.1.E	AW3.04B.23N.B12.1.E
	Cover and Cut				
	Excavation up to Elev. +36.15, Piles Pilecap			B12.1.E.01	AW3.04B.23N.B12.1.E.01
	Excavation up to Elev. +33.75, Concrete Cover slab Lean Concrete, Backfilling			B12.1.E.02	AW3.04B.23N.B12.1.E.02
	Excavation under the Cover Slab			B12.1.E.03	AW3.04B.23N.B12.1.E.03
	Open Excavation			B12.1.E.04	AW3.04B.23N.B12.1.E.04
	Cut & Cover				
	Excavation, Temporary Support			B12.1.E.05	AW3.04B.23N.B12.1.E.05
	Lean Concrete, Bottiom Slab, Side Walls, Top Slab			B12.1.E.06	AW3.04B.23N.B12.1.E.06
	Backfilling			B12.1.E.07	AW3.04B.23N.B12.1.E.07
	Underground works				
	Excavation Temporary support Phase 1			B12.1.E.08	AW3.04B.23N.B12.1.E.08
	Excavation Temporary support Phase 2			B12.1.E.09	AW3.04B.23N.B12.1.E.09
	Final Lining			B12.1.E.10	AW3.04B.23N.B12.1.E.10
	Tunnel finishing Works			B12.1.E.11	AW3.04B.23N.B12.1.E.11
	Tunnel XXX2	XXX%		B12.3	AW3.04B.23N.B12.3
	MAVRA LITHARIA EAST PORTAL (LEFT BRANCH)		XXX%	B12.3.EL	AW3.04B.23N.B12.3.EL
	Open Air works				
	Top soil and trees removal & drainage trench construction			B12.3.EL.01	AW3.04B.23N.B12.3.EL.01
	Excavation and temporary support measures (+28,00), shotcrete			B12.3.EL.02	AW3.04B.23N.B12.3.EL.02
	Excavation and temporary support measures to final level(18,71), shotcrete			B12.3.EL.03	AW3.04B.23N.B12.3.EL.03
	Pre-arch & connection with forepoles, shotcrete			B12.3.EL.04	AW3.04B.23N.B12.3.EL.04
	Open excavation & temporary supports of slopes			B12.3.EL.05	AW3.04B.23N.B12.3.EL.05
	Underground Works				
	Excavation Temporary Support Top Heading			B12.3.EL.06	AW3.04B.23N.B12.3.EL.06
	Excavation, temporary support Invert			B12.3.EL.07	AW3.04B.23N.B12.3.EL.07
	Final Lining			B12.3.EL.08	AW3.04B.23N.B12.3.EL.08
	Finishing works			B12.3.EL.09	AW3.04B.23N.B12.3.EL.09
	MAVRA LITHARIA EAST PORTAL (RIGHT BRANCH)		XXX%		
	Open Air works				
	Top soil and trees removal & drainage trench construction			B12.3.ER.01	AW3.04B.23N.B12.3.ER.01
	Excavation and temporary support measures (+28,00), shotcrete			B12.3.ER.02	AW3.04B.23N.B12.3.ER.02
	Excavation and temporary support measures to final level(18,60), shotcrete			B12.3.ER.03	AW3.04B.23N.B12.3.ER.03
	Pre-arch & connection with forepoles, shotcrete			B12.3.ER.04	AW3.04B.23N.B12.3.ER.04
	Open excavation & temporary supports of slopes			B12.3.ER.05	AW3.04B.23N.B12.3.ER.05
	Underground Works				
	Excavation Temporary Support Top Heading			B12.3.ER.06	AW3.04B.23N.B12.3.ER.06
	Excavation, temporary support Invert			B12.3.ER.07	AW3.04B.23N.B12.3.ER.07
	Final Lining			B12.3.ER.08	AW3.04B.23N.B12.3.ER.08
	Finishing works			B12.3.ER.09	AW3.04B.23N.B12.3.ER.09

It is important that the integration specification of the system to be developed must be initially found and categorized, and without these integration specifications the system development cannot be integrated and cannot be managed and be functional.

WBS is a dominant key in integrating the system, but it should be calculated properly, and in a way so that the project can be controlled.

The unique ID code that is described in this stage it has not been developed only for costing and budgeting the project. It also transfers valuable information of the activity or the structure about the risks, the variables in designs, the work method statements, the variable that may affect the cost, and more. This information regarding cost is recorded, categorized and used in the control stage according to the project's final process. This information is recalled for cost management purposes, and the system can include it or not in the process of comparison between the budgeting stage and control stage.

It is important that the method used to develop the estimation and the planning is precise enough to provide a basis for controlling and monitoring the desired construction throughout the detailed design process. A good budget should be supported by established design parameters and quality levels and then priced on a conceptual basis in enough detail to allow the control process to be effective. Target costing provides all the necessary information and cost requirements to proceed in budgeting the designs (Ballard, 2006). If the budget used to seek the project financing cannot be used in this fashion, then control during execution will be difficult or impossible to achieve (Parker, 1993).

Setting up the framework of the cost control stage early provides valuable flexibility to the managers so that they will be aware of what to expect when the control stage is reached. Performance reports, variance policy, forecasting procedures, requested changes and recommended corrective actions are some of the requirements that need to be set up in stage one before the integration process begins. Below is a short example of the construction of a portal of a tunnel, which will be viewed in the control stage after the integration and the system development procedures.

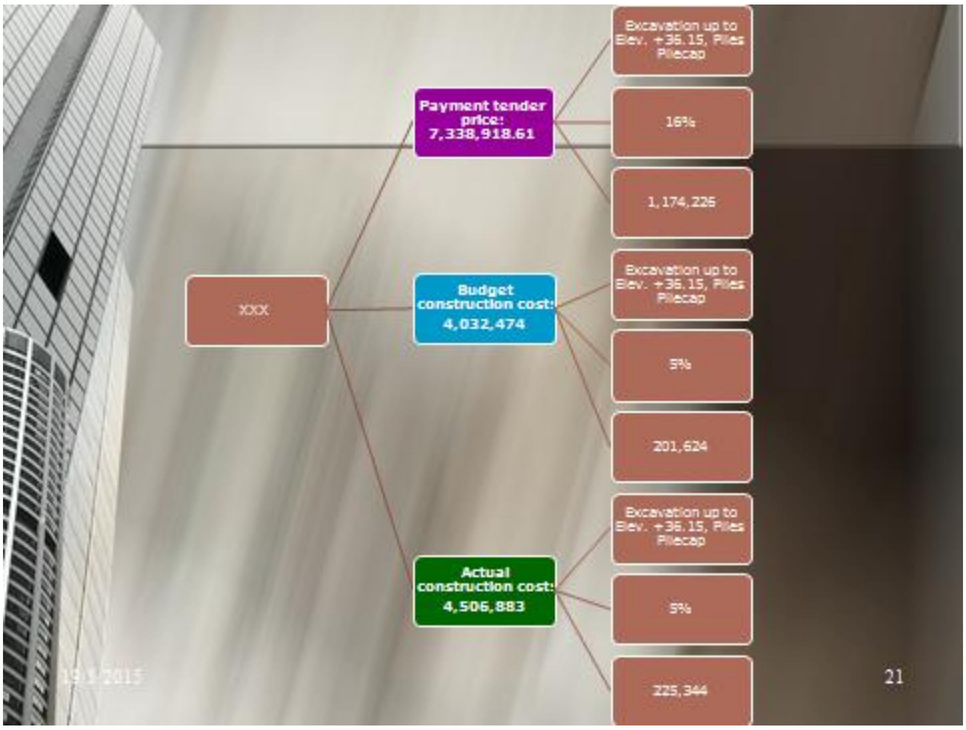


Figure 5.15: EVA analysis for Project Control-Actual Vs Budget Vs Tender (Source: Author's proposal)

In Figure 5.15, we see the tunnel structure and what the cost distribution in terms of payment tender is - the budgeting cost and the actual cost, both of which are needed to be compared with the EVA methodology.

A cost control system should serve as a link between the cost estimate and the actual construction or project cost. Its main objective is to maintain costs within the restrictions of the cost estimate or construction budget.

The control method investigated and chosen for this study is Earned Value Analysis (EVA). The EVA cost control method calculates only three variables: the actual cost performed on site, the dates of work performed (time sheets), and percentage of work accomplished (De Souza and Adler, 2015). Traditional cost control methods calculate only % complete estimate, % budget spent, % work done and % time elapsed. This is a subjective and incomplete approach and draws false conclusions. Instead, the EVA is an industrial way to measure a project's progress, forecast its completion date and final cost, and provide variances along the way. With the integration of just three measurements (BCWS: Budgeted cost of work scheduled, BCWP: Budgeted cost of work performed, ACWP: Actual cost of work performed), EVA provides consistent, numerical indicators with which projects can be evaluated and compared Figure 5.16, 5.17, 5.18 & 5.19.

Figure 5.16: Set Up EVA analysis for Project Control-Basic Table report (Source: Author's proposal)

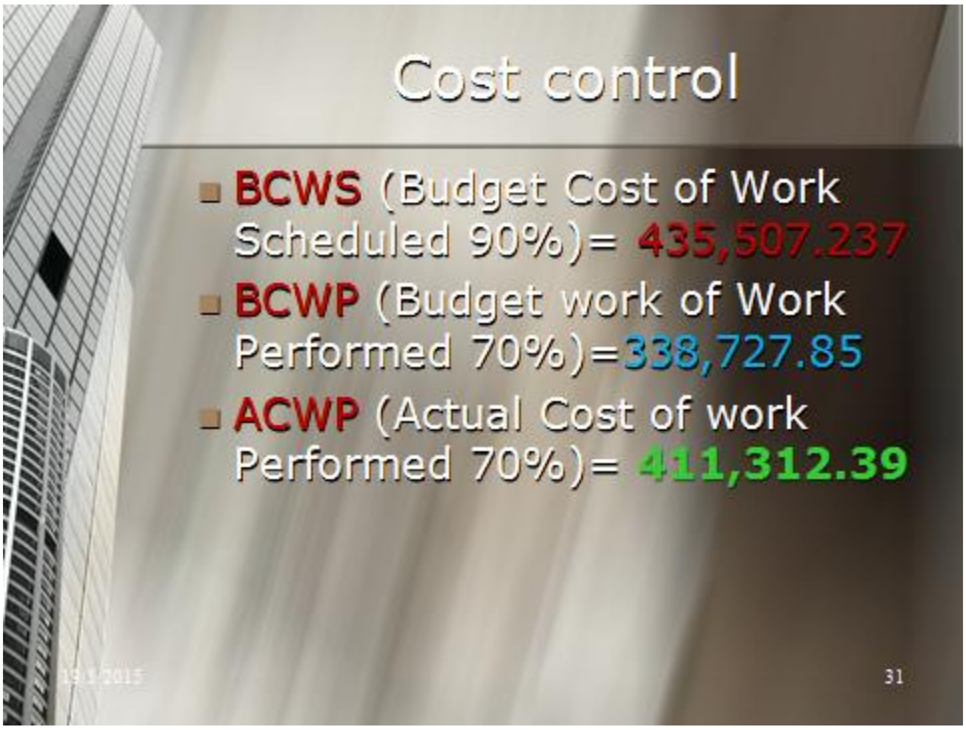


Figure 5.17: Set Up EVA analysis for Project Control- EVA Values (Source: Author's proposal)

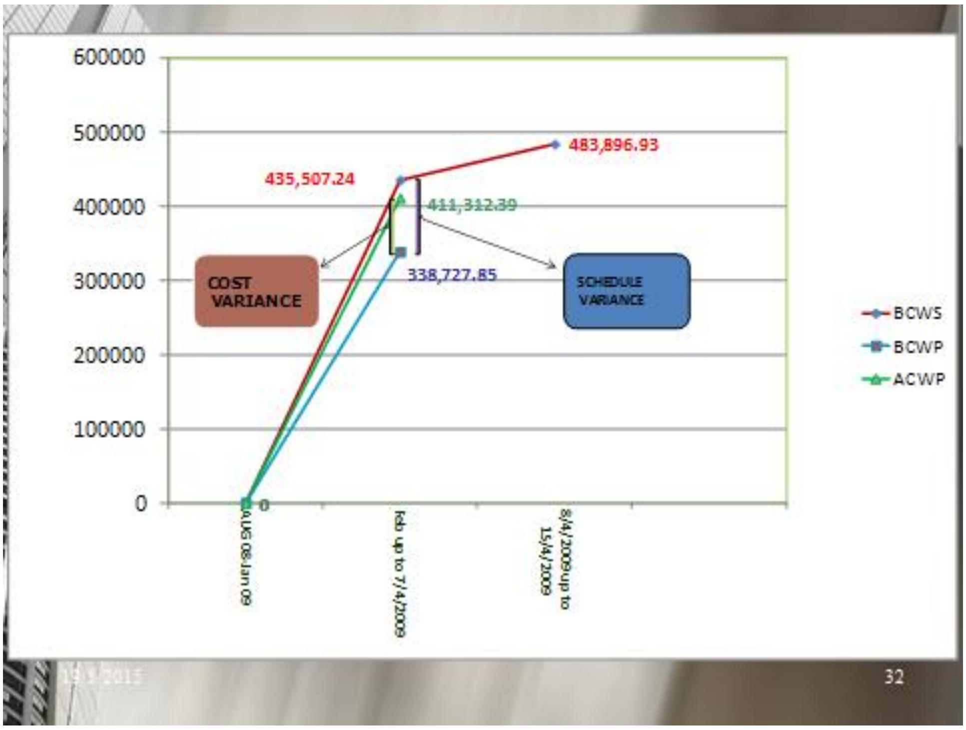
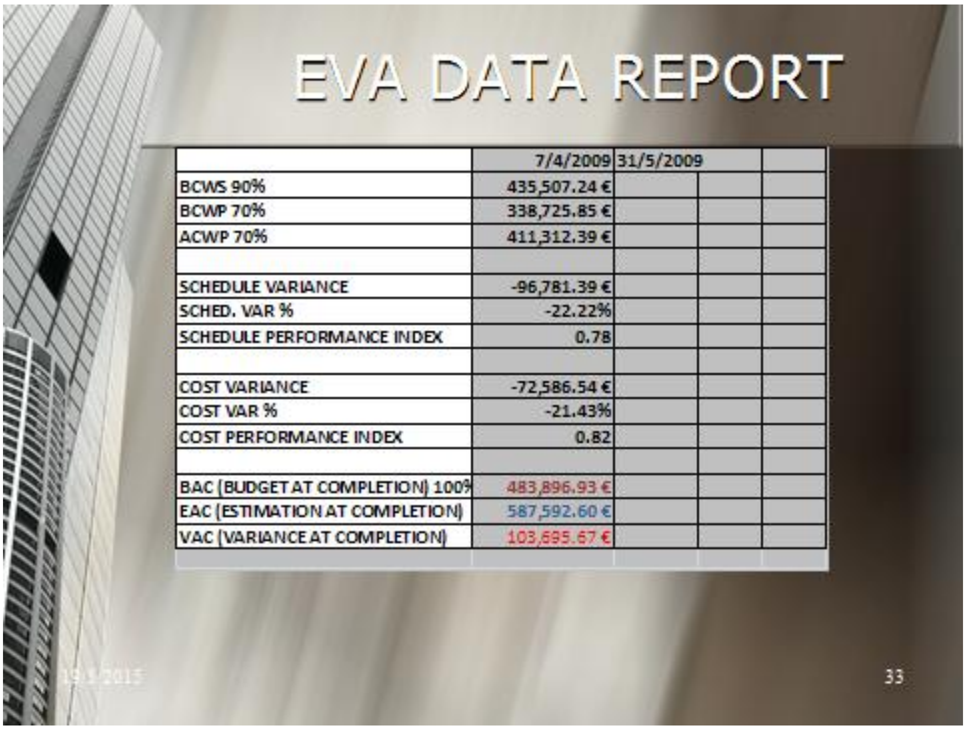


Figure 5.18: Set Up EVA analysis for Project Control-EVA Presentation (Source: Author's proposal)



	7/4/2009	31/5/2009		
BCWS 90%	435,507.24 €			
BCWP 70%	338,725.85 €			
ACWP 70%	411,312.39 €			
SCHEDULE VARIANCE	-96,781.39 €			
SCHED. VAR %	-22.22%			
SCHEDULE PERFORMANCE INDEX	0.78			
COST VARIANCE	-72,586.54 €			
COST VAR %	-21.43%			
COST PERFORMANCE INDEX	0.82			
BAC (BUDGET AT COMPLETION) 100%	483,896.93 €			
EAC (ESTIMATION AT COMPLETION)	587,592.60 €			
VAC (VARIANCE AT COMPLETION)	103,695.67 €			

Figure 5.19: Set-up EVA analysis for Project Control- EVA Indices Report (Source: Author's proposal)

The cost control system must follow the framework of the estimation, thus a real and full comparison between budget cost and real cost is available in any level and any period of construction (Narbaev et al., 2015).

In simple words, it compares the planned amount of work with what has been completed to determine if cost, schedule and work accomplished are progressing as planned, as shown in Figure 5.20.

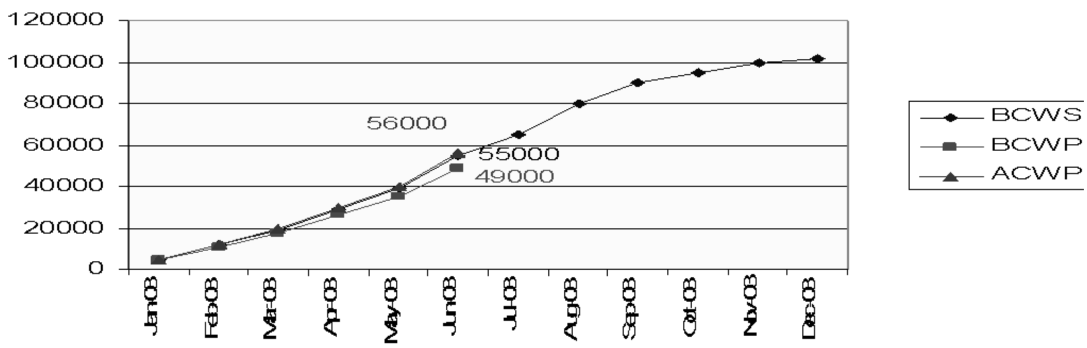


Figure 5.20: Earned Value Analysis diagram (Source: NOOA, 2003, www.cio.noaa.gov/itmanagement/evaslides.ppt)

The cost estimation and cost control system must be designed within a complete information system for the whole project delivery system stages. This is called the Project Information System (PIS), and the cost management system is only one part that this analysis investigates. The PIS generates and transfers any information related to the project needs.

Construction projects inevitably generate enormous and complex sets of information. Effectively managing this bulk of information to ensure its availability and accuracy is an important managerial task. Poor or missing information can readily lead to project delays, uneconomical decisions, or even the complete failure of the desired facility. With better information, problems can be identified earlier so that, for example, alternative suppliers might have been located or schedules arranged. Both project design and control are crucially dependent upon accurate and timely information, as well as the ability to use this information effectively. At the same time, too much unorganized information presented to managers can result in confusion and paralysis of decision making (Hendrickson, 1998).

The literature highlighted the need to prepare estimates with an emphasis on managing the cost and use of the information provided in the planning stage to control the construction cost efficiently, yet not much research has been carried out in this field.

The main idea of the integrated cost estimation and cost control system is that estimation data are transferred automatically to the control process. A basic requirement for this transformation to succeed is to develop or generate a coding system that can ensure the uniqueness of each activity and work package. The Work Breakdown Structure (WBS) is the basic input in such a system and can provide valuable information in many levels of hierarchy.

The requirements needed to prepare cost estimates in accordance with efficient cost control are inherent in the proposed integrated cost management framework of Table 5.1. These requirements are grouped in “inputs’, “outputs” and a “process” for each project stage. The inputs start in the very early stages, with the emphasis on client needs, target costing and basic project specifications to proceed in the planning process. It is important to mention that outputs such as resources policy and cost control policy are presented in the planning stage before the construction starts. Hence, more action policies are developed and more flexibility is generated to manage cost before construction starts. The framework requirements proposed in Table 5.1 meet the project delivery stages, providing information and feedback at any stage of the project life cycle. Early planning is the key requirement of the current framework. The four stages of project delivery start in the early stages of the project with project inception, and are completed in the control stage during construction (Forbes, 2011). The cost management system stages that are presented in Figure 5.21 follow the time process of the Lean Project delivery system described by Ballard (2008). Figure 5.21 sets the framework described in Figure 5.12 under the Lean approach to delivery of projects in an attempt to explain that even the Lean Project Delivery System follows the Cost Management stages of delivering the projects.

Project Definition: is the early beginning project phase which starts with the feasibility study, the purposes of the project and basic design concepts. Client constraints usually are set in this project phase.

Lean Design: follows the Project definition by using design concepts and other project specifications to produce analytical designs with resources and other project elements.

Lean Supply: is the phase which the resources and other project specifications are analyzed further. By this stage, a policy of how these resources and elements will be used in the construction process is drawn up, and it is the last action of the planning process of each project, just before the work starts and the resources arrive onsite.

Lean Assembly: is the phase beginning with the first delivery of resources to the site and ending with project turnover. In other words, it is the control stage of the project and, in terms of cost, is the project cost control phase.

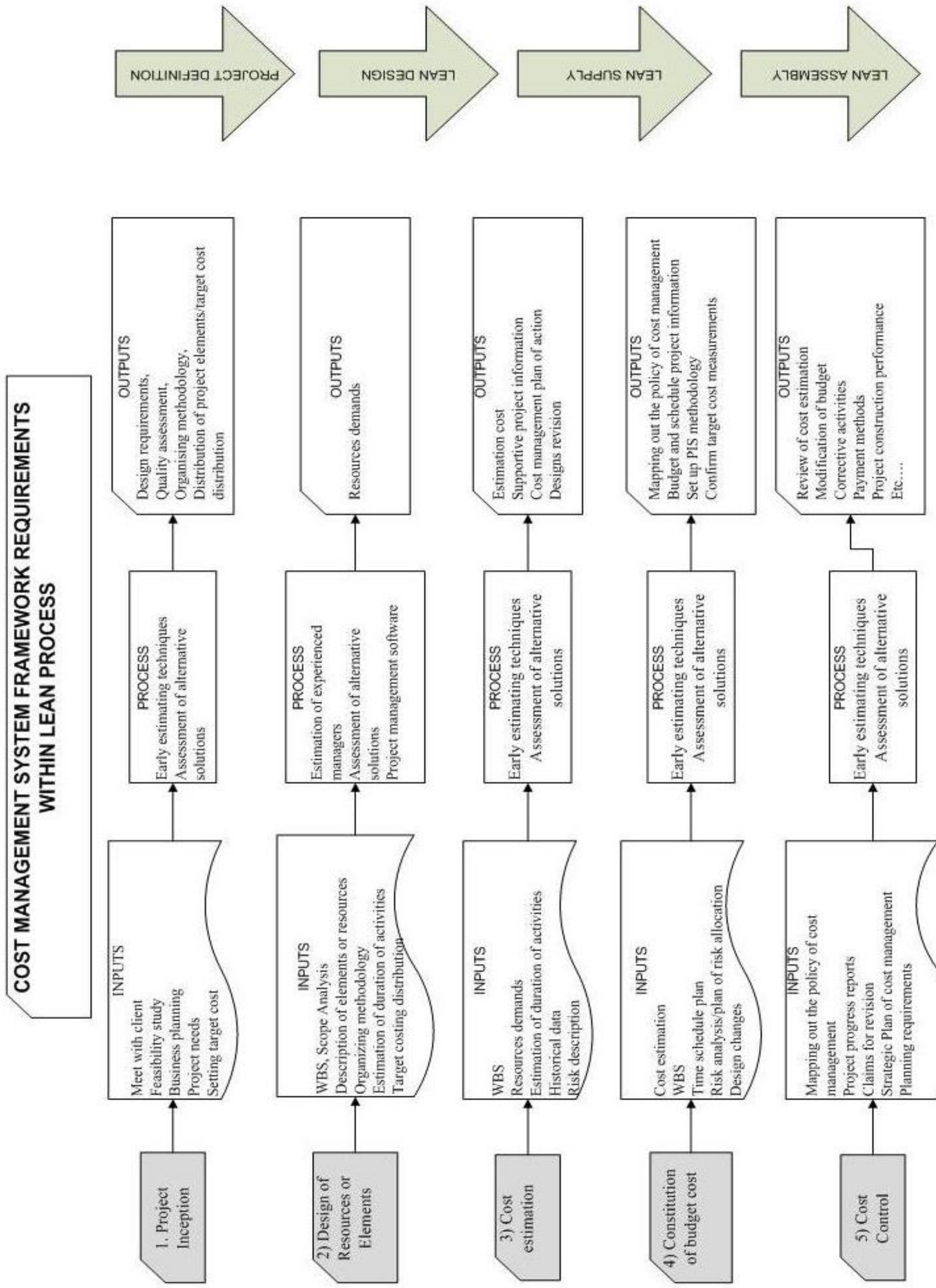


Figure 5.21: Development of cost management framework system requirements (Source: Author's proposal)

The framework of system requirements provides a common structure between the planning and control parts in which the outputs of the planning process are used as inputs in the control process through the uniqueness of the coding system. This framework is an effective tool in developing an information system, and the requirements described have been used to develop a prototype cost management model. The process time development appears in Figure 5.12. The horizontal axis of Figure 5.12 presents the time process to develop the prototype model, starting with model analysis and requirements, continuing with development of the actual cost management model, and culminating with the final parameterization and applications on real projects. On the other hand, the vertical axis describes the time required for the model process by using the inputs of the proposed management system, and how these inputs are processed, and gives the final model approval. It is important to note that the revision processes are related to the time process, and the feedback process always occurs after the first analysis of the inputs, as shown in Figure 5.12. This ensures the model efficiency and that more reliable cost information data is generated.

This study is the starting point for the final integrated cost management system development. The following objective is an in-depth analysis of the integration system and the development of a prototype model based on the current framework. The system will be applied within the PIS under the Project delivery specifications, and real project tests will be made to ensure the system's efficiency.

The purpose of developing the framework of an integrated cost management system under Process is achieved and provides important information regarding the system's requirements.

Early planning procedures that are used in this framework, such as target costing, mapping resources and cost control policy, ensure the effectiveness of the cost management system. Furthermore, the time process to develop the integrated system based on these framework requirements is based only on three steps, as shown on Figure 5.12: model analysis, model development and application, which will ensure quick feedback in any project that the system may be applied to.

In construction, work is released by an administrative act: planning. In this sense, construction is directives driven, and so measuring and improving the planning system performance is the key to improving work flow reliability.

The construction, and specifically project, delivery system aims to maximize performance for the customers at the project level through the concurrent design of product and process and the application of production control throughout the life of the product from design to delivery. The Project delivery process, together with the integrated cost management system, supports the development of team work and a willingness to shift burdens along the supply chain. Partnering relationships coupled with lean thinking make rapid implementation possible. Of course, people manage systems and this integrated system is not an exception, but there is a need to focus on how these systems affect the projects instead of trying to maximize their performance first.

The introduction of target costing methodology and its application in the early stages of Project delivery process reduces the waste of the design-estimate-rework cycle, thus increasing the value clients get for their money.

The common structure of the cost management system under the Project delivery Process can ensure a reliable comparison of estimated and real cost values. It is also able to identify the needs of such a system within a complete information system, and what the benefits of using PIS are. The investigation of current cost management approaches and methods highlighted the shortcomings of current methodologies used, and it is much more than ever before necessary to provide an alternative in cost management processes.

The new integrated cost management system can provide any information relating to project progress in terms of cost and schedule. It is a powerful tool which, if combined with other features of the PIS and applied in a Project delivery basis, can provide results related to the operation of the company and the performance of labor. Finally, it prevents delays and cost overruns and stimulates action plans to keep the project as planned and, together with Project delivery, acts as a process to manage the projects ensuring better customer needs are met and value within projects is maximised.

5.7 INTEGRATED SYSTEM AND APPLICATION ENVIRONMENT: STAGE TWO

The cost management processes described are used in the project delivery stages from inception to the use stage. The integration process that this study analyzes will provide a complete integration cost management system with an emphasis on the links of these processes and the feedbacks from one process to the other.

Table 5.1 provides an overview of the project cost management processes, the requirements and the outcomes and their links integrated into one single system operating process.

Table 5.10 shows the Proposed Project Cost Management process and integration linkages. In this section the integration system prototype development within the PIS environment is described.

5.7.1 FRAMEWORK OF COST MANAGEMENT SYSTEM-PROPOSED INTEGRATED COST MANAGEMENT SYSTEM AND SYSTEM APPLICATION-PROTOTYPE VERSION

It is important that the method used to develop the project budget is precise enough to provide a basis for controlling and monitoring the desired building throughout the detailed design process. A good budget should be supported by established design parameters and quality levels and then priced on a conceptual basis in enough detail to allow the control process to be effective (Theodorakopoulos, 2009). Since the integration has been applied in the proposed system an application model to support the system has been developed which uses the proposed integrated system and its components. The time process of developing a prototype cost management model has been already described and analyzed in Figure 5.12. The alpha prototype version of the system is the second stage in the time process of the completion of the integrated system. The IS development, which is analyzed Figure 5.22, provides all the necessary tools to integrate the system into many project categories according to their needs and meeting their project targets.

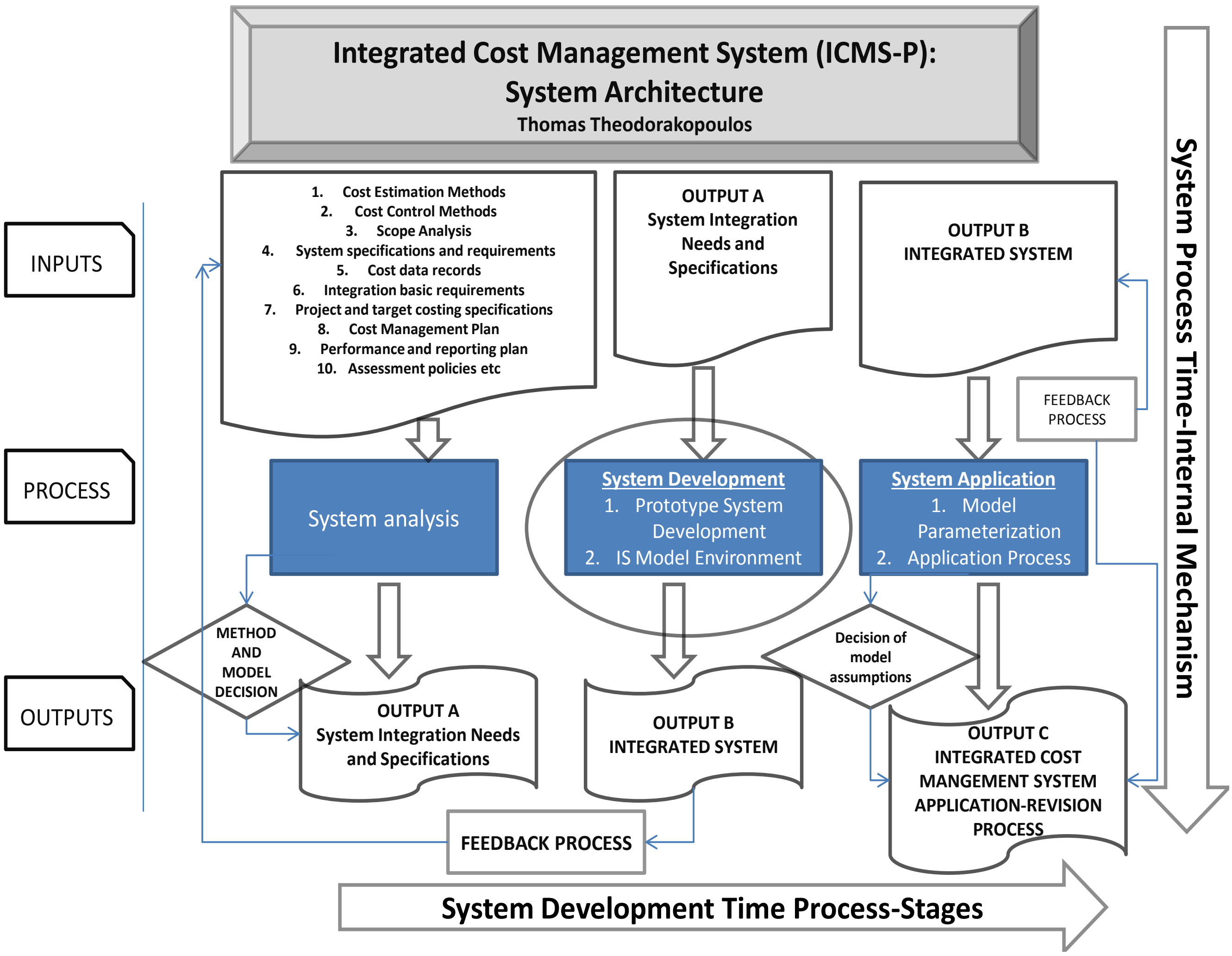


Figure 5.22: System Development Time Process Step 2 (Source: Author's proposal)

5.7.2 Integrated System Development and Software Environment

This analysis uses the total project cost according to the cost estimation method chosen and the various project features. The system application consists of two main components: the budgeting cost database environment and the actual cost database environment. An illustration of these two environments is showing in Figure 5.23 showing the integration concept of estimation, planning and control stages.

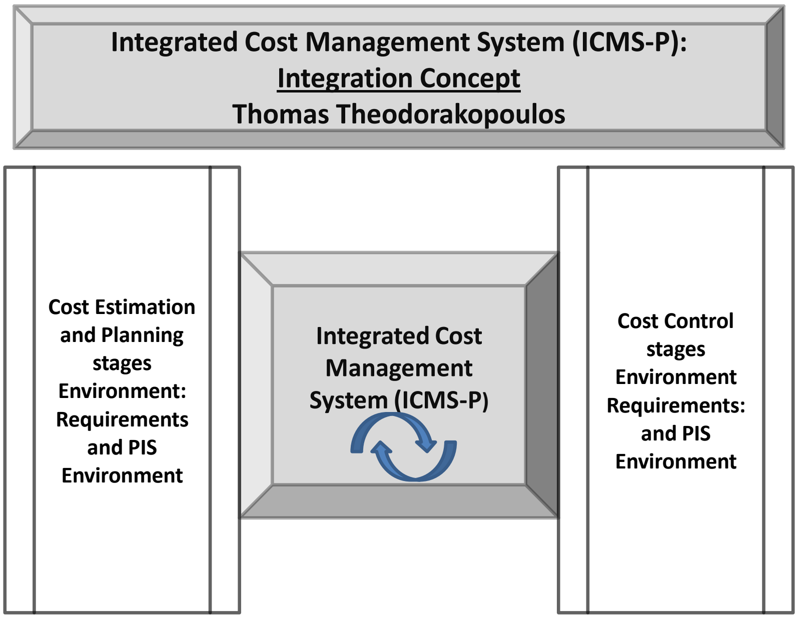


Figure 5.23: Integration illustration concept (Source: Author's proposal)

The budgeting cost database environment and the actual cost database environment are both presented in Figure 5.21 and Figure 5.22 respectively. Both planning and control databases follow the same WBS structure in various levels in a unique ID coding system, as explained previously in the chapter, allowing the full integration process between the budgeting and control stage.

The WBS structure allows the development of a system in which all activities are described in such a way that any comparison between the budgeting environment and the actual environment can be made vertically or horizontally.

Establishing the budgeting cost environment is a prerequisite to preparing all these activities, so the budgeting environment needs to be integrated with the actual cost environment.

To solve this problem in this initial stage, export and import files were created which will prevent any human or user errors in the process. These export and import files are related to materials, subcontractors, plants, and labor cost. The unique ID coding system allows any excel file based on this WBS structure in any level of the project to be extracted.

Below are shown some examples extracted from the system and the system application development framework, and how these two environments work together in a unified process.

Figure 5.24 shows an example extracted from the budgeting cost database related to the budgeting of a bridge construction in phases. Participation weight factors are used in the budgeting process, depending on the nature of the structure. Hence, a complete budget for all project activities has been successfully achieved.

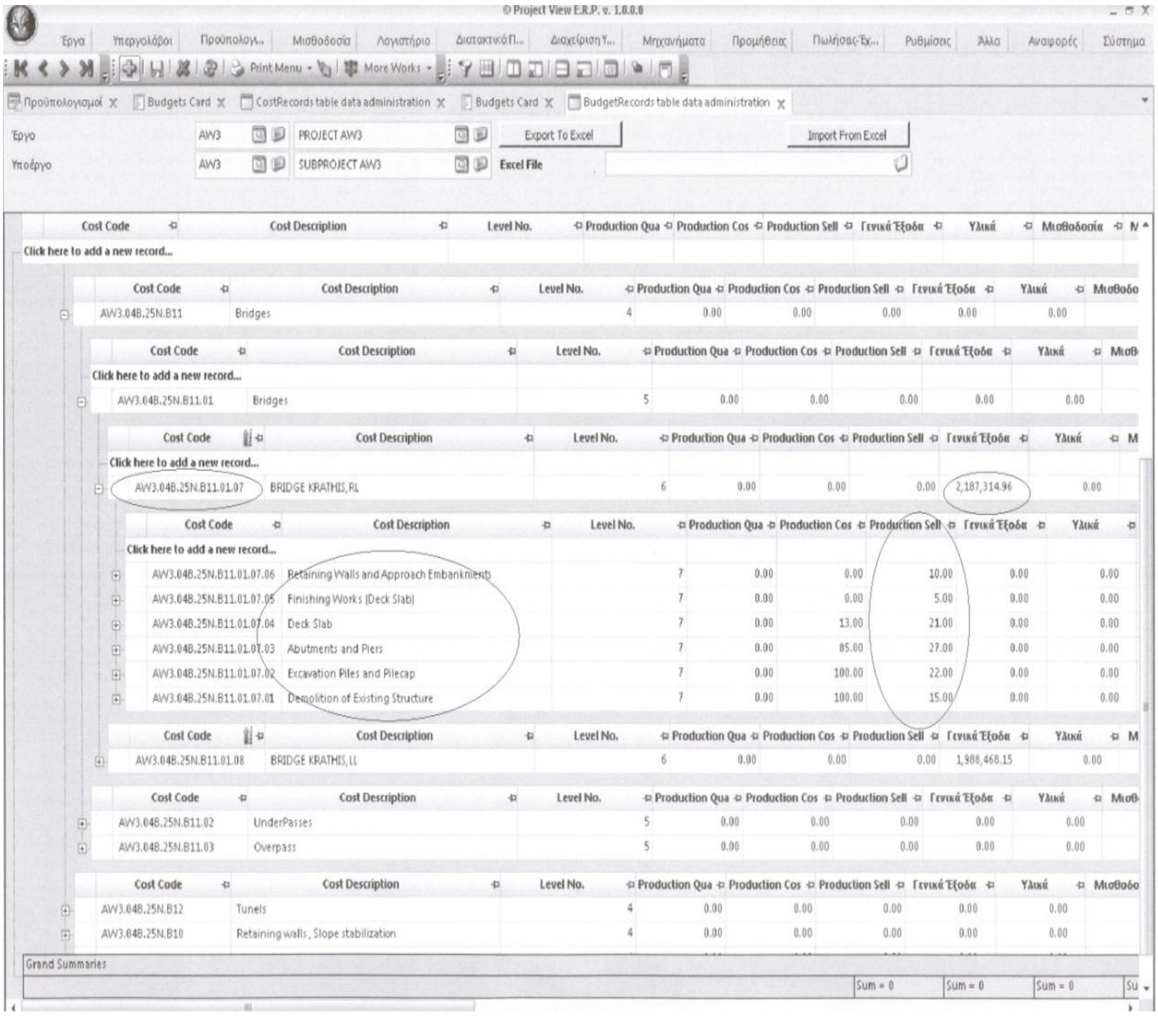


Figure 5.24: Budgeting WBS environment -Bridge Construction Budgeting Process (Source: Author's proposal)

The budgeting environment can be presented analytically or synoptically to any of the levels of hierarchy of the project. The specific extracted figure shows, among others, the budgeting of a bridge and its components.

The unique ID system and code of the bridge right branch and the ID codes of each specific stage of construction can be clearly seen. (Analytically this will be explained in the case study, together with all the details of the budgeting and actual costs).

The integrated system to manage cost in any form or variable transforms any of those variables to participation in total activity cost. Therefore, it is known that each specific stage participates, at some percentage, to the final cost of the bridge. It does not matter if the cost of abutments and piers is more expensive to contract compared to the cost of piles because effort is already included in the participation cost as a variable. Thus, by that stage, all these factors affecting cost and effort to achieve it have been included within the system. The individual stage cost initiates the total cost of the activity.

This cost is the budget of the activity, and the reference for any future comparison with actual cost. The budgeting environment involves exporting and importing excel files all related to budgeting the activities of the project and, at the same time, it enters all that information related to the activity into the system so that it may be recalled in the future.

Following the procedure of integration of both the budgeting and control stage, the actual cost database must be filled in throughout the project construction period, as shown in Figure 5.25. In this database, the identical WBS taken from budgeting procedure but filled in with actual cost information derived from the construction site is clearly presented. This actual cost is distributed across the five basic cost categories: personnel, plant, materials, subcontractors and general expenses. All cost information is imported to the database by using simple excel files from the project diary, without the risk of operator errors. Therefore, the actual cost database provides a clear picture of the cost occurred at any level of the project.

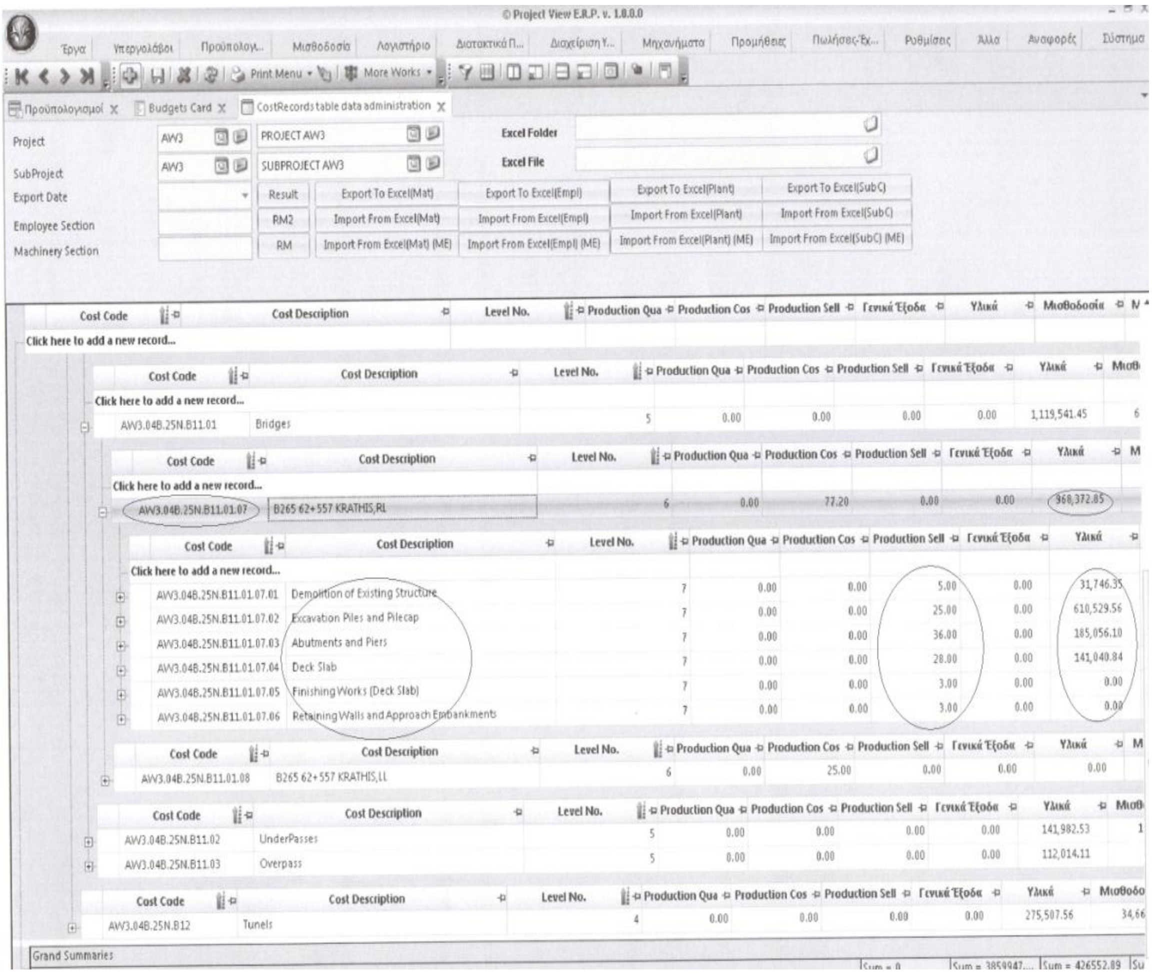


Figure 5.25: Actual Cost WBS environment-Bridge Construction Control Process (Source: Author's proposal)

The actual cost environment is identical to the budgeting cost environment in terms of structure and information provided. As explained, all information is derived from excel files taken from the construction site with minimum required information. When this information is written, the file is imported again to the system and located to the specific ID code and cost basis code. In Figure 5.25 the weight participation of the bridge construction stages and the actual costs from a specific progress point of the construction are presented. On the top of the figure the package of exported and imported files is clearly shown and described. The options are unlimited in terms of exporting and importing information due to the levels of the project control decided upon. In Figure 5.22, a seven level system, which is a very detailed analysis, has been chosen to be shown.

Both Budgeting and Actual cost environments are the summary figures, and all the information is taken from the hidden structures and calculations.

The purpose is to provide the simplest information possible so as not to confuse the operators or the managers with information that is not important at that stage or not needed, but could be recalled anytime throughout the process.

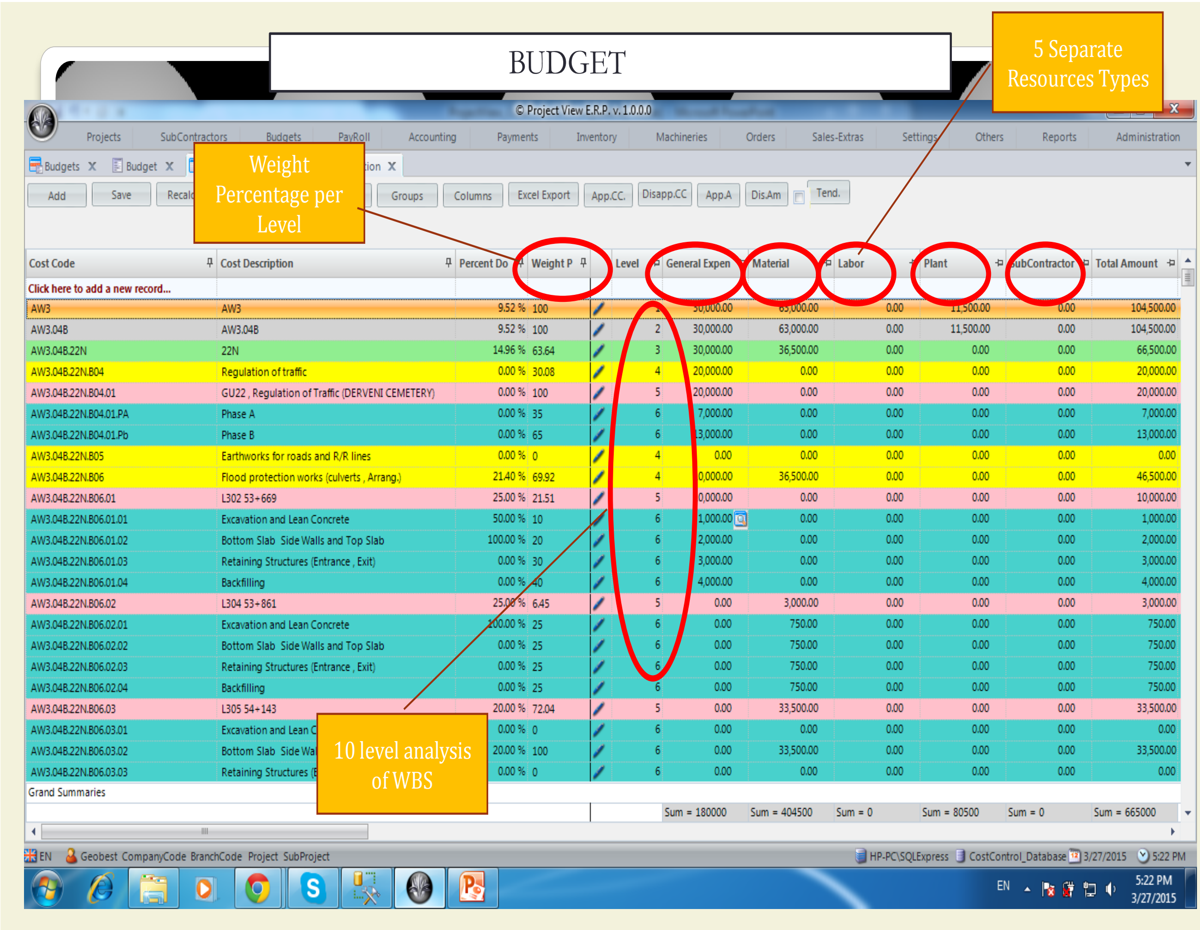


Figure 5.26: Different format of presenting the budgeting environment (Source: Author's proposal)

Figure 5.26 presents a different format of budgeting a cost environment which shows the full extracted and detailed analysis (here, only a few items from the whole project are included) of structures and their stages.

This format allows operators and managers to work with a horizontal analysis of the budget based on five cost categories: General expenses, Material, Labour, Plant, Subcontractor and, finally, the total amount as a summation.

Weight factors are also included in this format, together with the levels of WBS and the knowledge, in each stage or activity or structure, of what level we are currently working in.

This format is useful when the budget has been completed and could providethe whole project budget or highlight specific structures to the managers for their information and/or use.

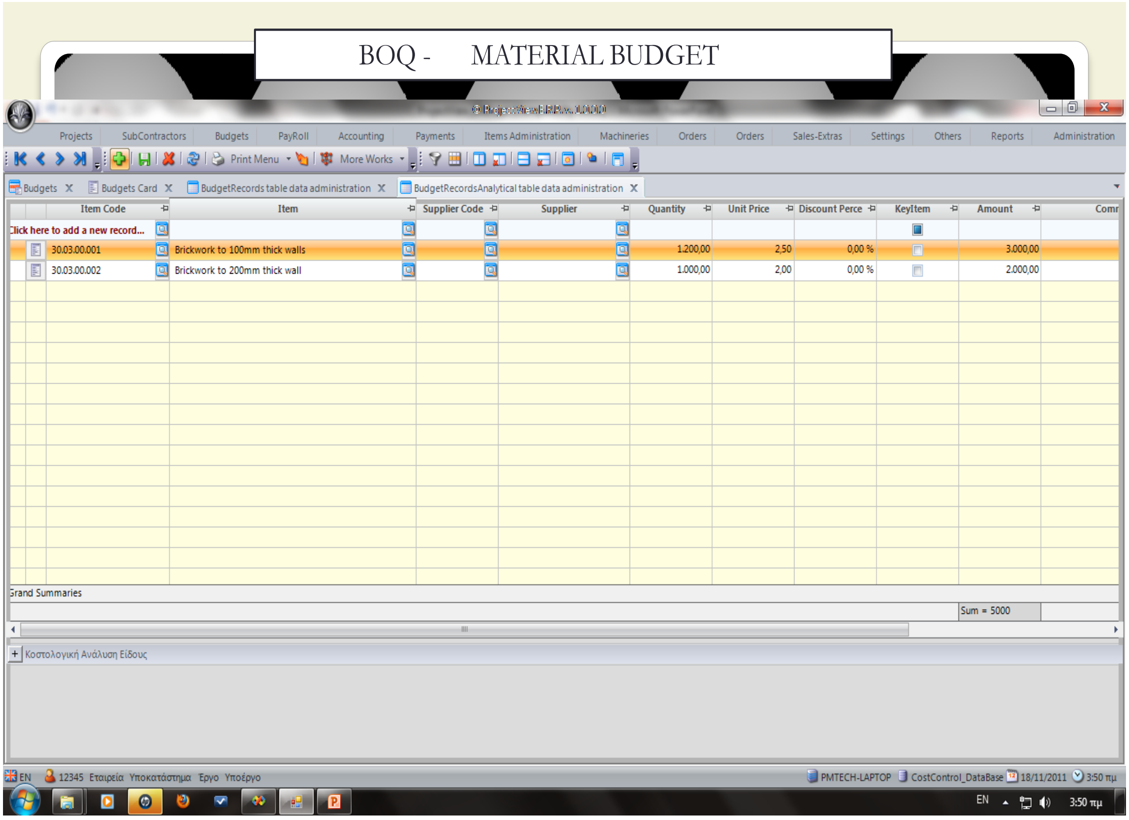


Figure 5.27: Material Budget environment (Source: Author's proposal)

The material budget is a full budgeting information system and, at the same time, one of the most important databases for the project and futures projects as well. Figure 5.27 involves the generation of unique ID item codes. These codes are assigned to the activity later while the project is being budgeted. We have two main options, and from those options many other subcategories may emerge. The first option is to prepare a complete material database with all the quantities needed in the project as well as the unit rate. This option is chosen by project managers in cases where they need to know the whole contribution of the reinforcement, for example, in the whole project so a better price could be arranged in the market. The other option is to establish a specific item only for a specific activity. In this way, we have a complete match of the material and the activity. This option allows us a clear picture of the activity or the structure, with all items of materials included. Both options are valid and could be used with the same results.

In the first option, there is the risk of assigning multiple times the same material in the same activity, and this will possibly lead to errors. The biggest advantage of the first option is that the database is short and easier to control compared to the second option, in which reinforcement is shown possibly a hundred of times and with different ID item code.

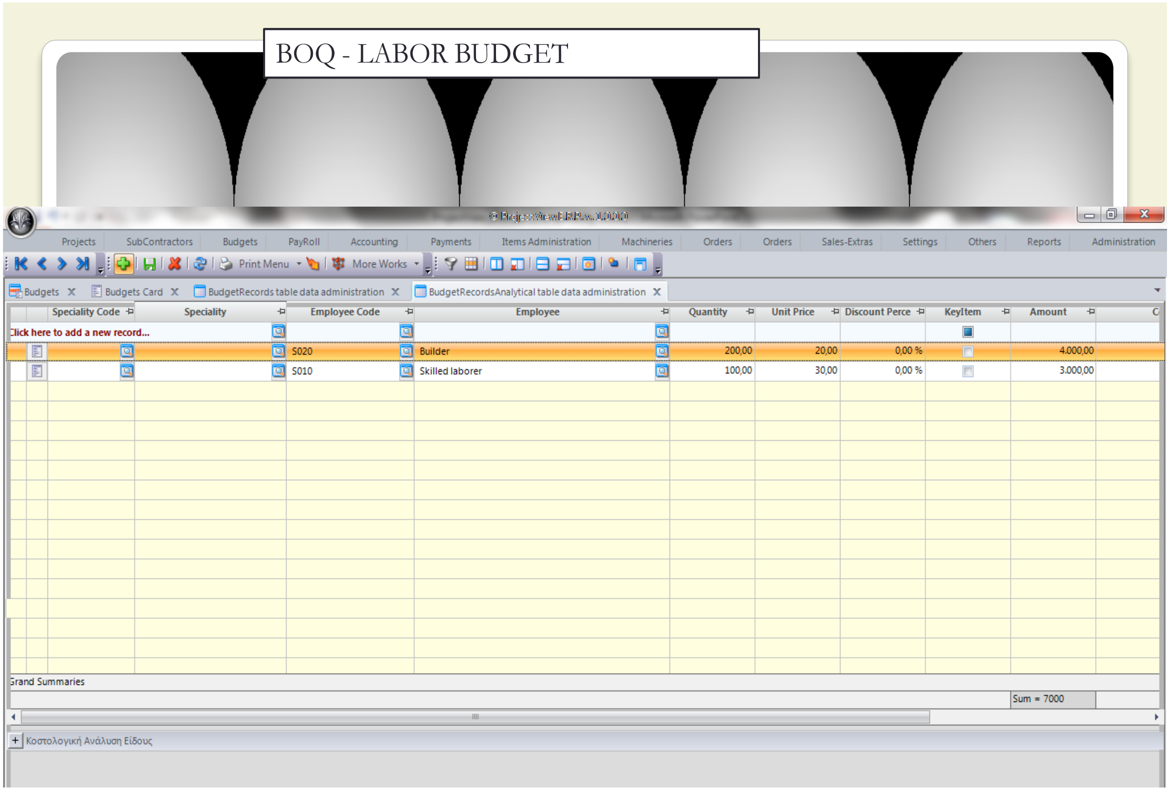


Figure 5.28: Labour Budget environment (Source: Author's proposal)

Figure 5.26 shows the labour budget environment and its components. This environment creates the labour and employee costs. It could be argued that this environment is the easiest of the cost basis categories because the ID code refers to a specific name, with specific employment status, and each name has its own characteristics. Operators, drivers, special technicians, labour, supporting staff and other categories could be used to identify the nature of the work of each specific person.

Each person can match with more than one activity or each activity match with more than one employee. There is always an opportunity to transfer the rates from money/hour to money/day or money/month or year. At the same time, there is the ability to provide participation in an activity by each person separately or participation based on his cost on the project. The status of the person includes the assigned activities that he works on, whether he completed his work or not. This information is valid in the control stage to manage people's effort and status.

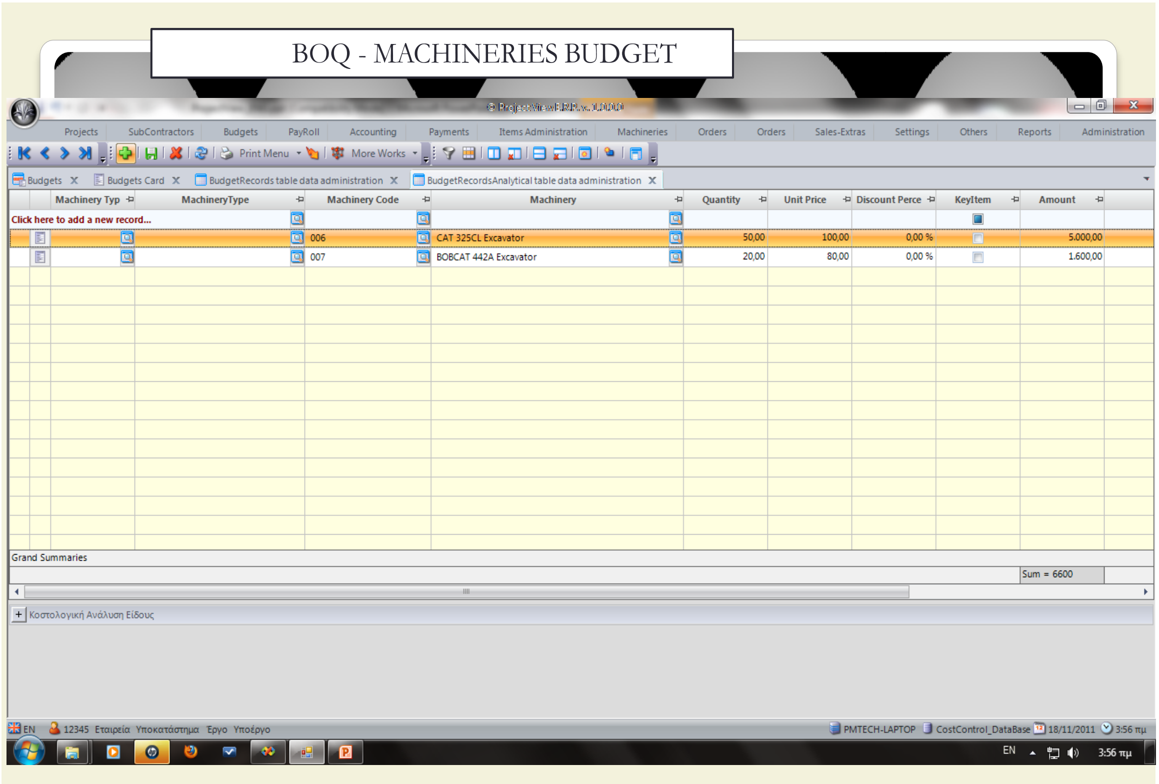


Figure 5.29: Machineries Budget environment (Source: Author's proposal)

Figure 5.29 represents the machineries budget environment. This table includes all the plant and machineries involved in the project. Similar to the personnel table, each plant has its own ID code and could be assigned to as many activities as required. Apart from the rate costs, which include diesel consumption rates, insurance and IRR rates (Investment Returns Rates), it includes any maintenance costs. Maintenance costs are very important due to the high cost of damages occurring in a project. These costs are assigned initially as actual material costs, but are also assigned in the cost of the plant and machinery itself. It is the decision of the project manager where the maintenance costs are best assigned. This option is very useful for a contractor or client to check if the specific item is not functional or has accumulated extra maintenance costs that were not estimated in the budgeting and estimating environment.

Machineries are also categorised in groups to provide a clearer picture for each activity, what kind of plants have been used, and for how long.

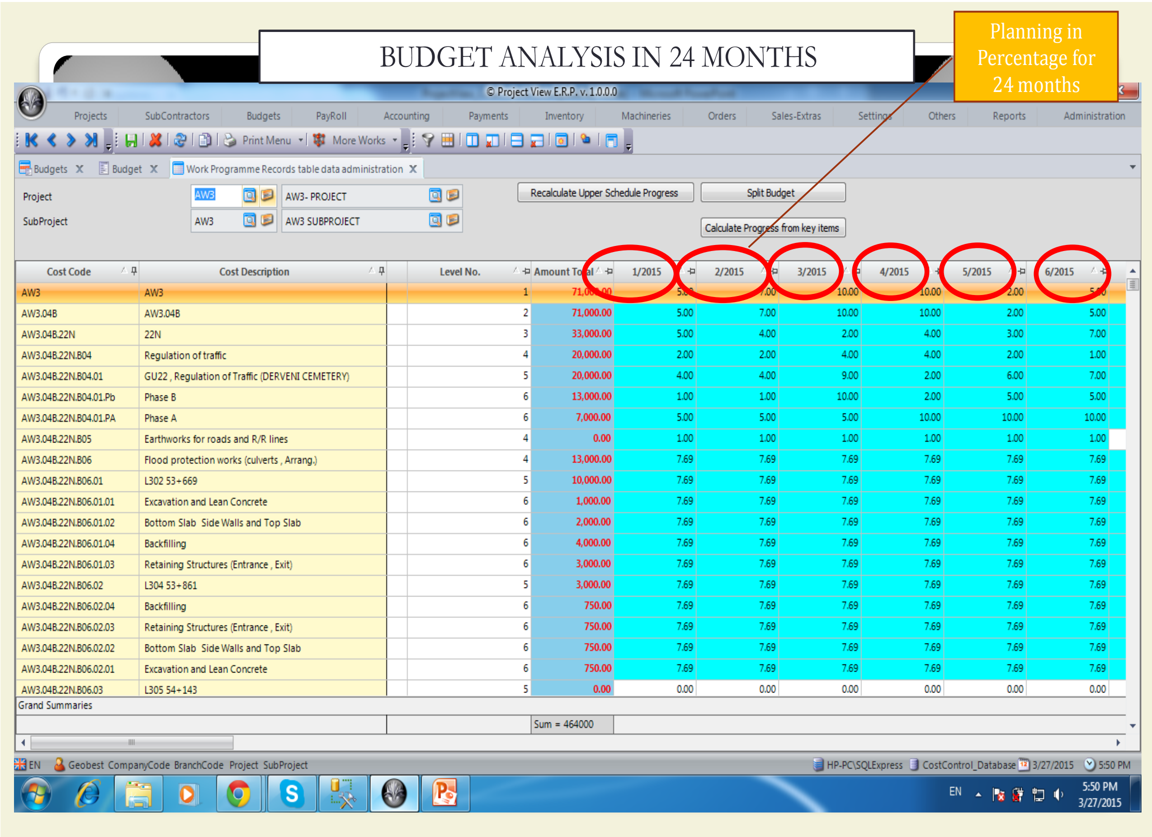


Figure 5.30: Budget Analysis in specific period needed. Percentage Factors (Source: Author's proposal)

Figure 5.30 is a very important table and a very innovative one because it takes all the budgeting information created and provides a very useful picture of the budget extended over time and which will help the manager to prepare his procurement policy and his strategy in resources.

It shows the ID codes of each activity, the Activity description, what level this is currently investigating and, on a monthly basis, how much of each activity in percentage method is to be executed according to the budgeting plan. This is fully compared with the actual cost environment and the actual execution progress of the activities.

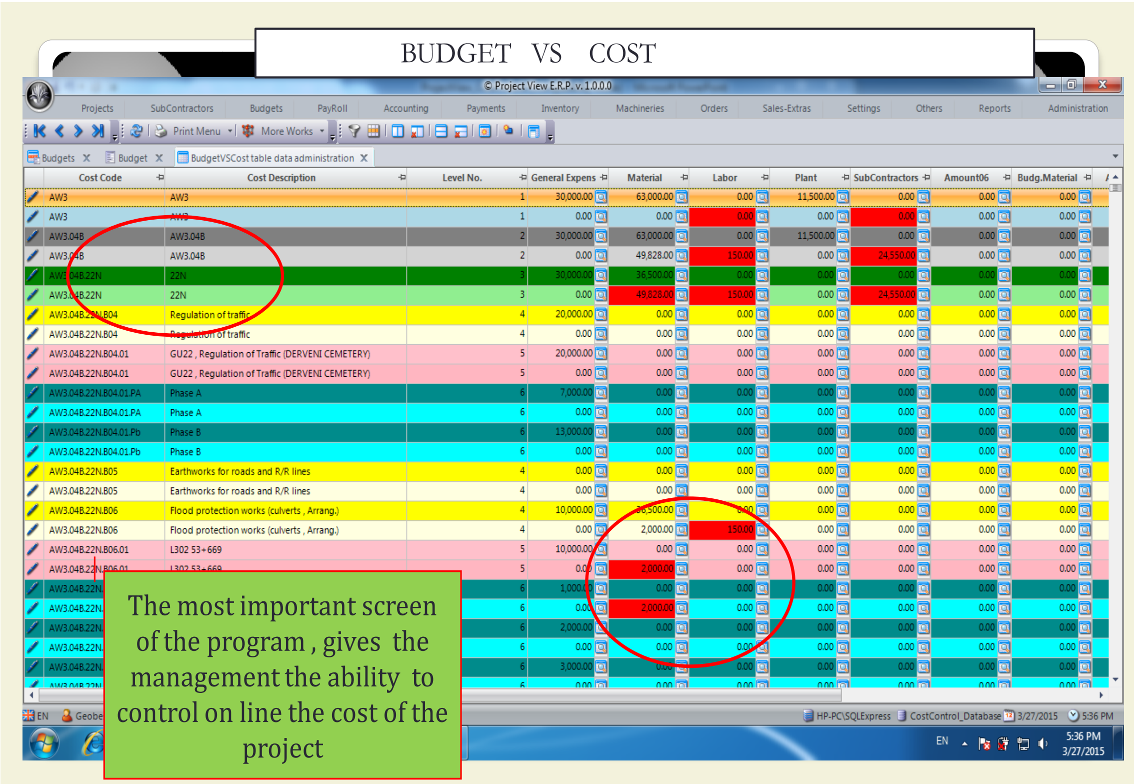


Figure 5.31: Budget Analysis in specific period needed. Percentage Factors (Source: Author's proposal)

Figure 5.31 and the table that is presented here is one of the most valuable tables of the system and model development. This is because it has succeeded in creating a very simple and full comparison between actual and budget cost. In terms of budgeting cost, any primary information regarding activity is included in this table in a single line. Below that line is the same activity with the actual cost in current progress. When this cost is exceeded in any way, the initial budgeting cost then becomes red and a whole report to the manager is provided explaining where this cost has been exceeded and what caused this over- budgeting. The importance of this table is that with just one picture or table, each manager or director may make significant budgeting decisions.

The innovation of this format and table is the use of real time and online control. This real-time process enables users to manage situations before it is too late. This tool, in construction projects, is very helpful from starting the construction stage up to the finishing stage.

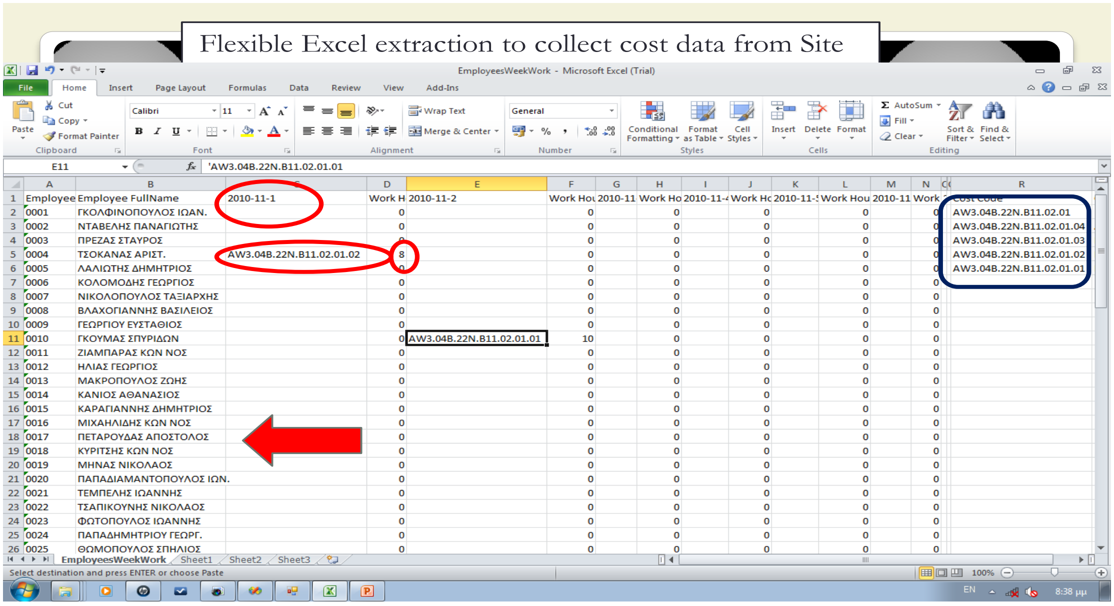


Figure 5.32: Excel files for import and export (Source: Author's proposal)

Figure 5.32 represents one of the excel files series that is used as an input to the system with valuable information. It has been programmed to use only the unique ID codes to establish cost. The operators and users do not need to calculate or manage any cost actions, only to assign the proper ID code, in this case the name of the person, to the specific ID activity. The excel files have been set on a weekly and daily basis according to the needs of the project and the capability of the site to control these files. This format can be monthly or annual according to project manager's decision.

In the budget stage, this excel worksheet is exported empty from the basic budgeting format table or from the employee's table. When it is imported, all activities are automatically recalculated in terms of cost and information taken from the construction site.

All the above figures illustrate parts of the total integrated system that has been developed. The successful integration of the main four stages of the project provides any kind of information required through a unique project information system that has been created to support the system. It could be argued that the process follows the needs of the project, and at the same time is a guide for further actions taken in the set- up process. The integration process has been successfully developed with the use of the requirements as described in the examples, and with the use of the available methodologies in each stage of the cost management stage. The application environment has been developed so the system can be presented in a readable and manageable way

With the successful approach to development of the system through alpha version development, the integrated system, which is now ready to be parameterized according to project needs, has been produced.

5.7.3 REPORTING SYSTEM AND COST CONTROL

Since actual cost information is being imported to the system, the system application is able now to calculate valuable reports supporting any decision making or actions to put the project back on track.

IS application system data information is used to provide simple and reliable reports through a second analysis which has been described as Earned Value Analysis (EVA). EVA is a project control technique which integrates cost, schedules and technical performance. It provides the earned value of a completed work and compares it with actual cost and planned cost to determine the project performance, and forecast its future trends. (Khamidi, 2011). EVA provides consistent numerical indicators with which projects can be evaluated and compared (Theodorakopoulos, 2009). The EV analysis is an integrated remote monitoring technique for complex interactions between the time and cost parameters to provide the performance measurements of a whole project. It is an effective and useful tool that can follow the integration analysis of budgeting and actual costs described previously.

Figures 5.33 & 5.34 are reports which have been extracted from the prototype integrated cost model, giving information on the progress of the project. A real bridge construction has been chosen as an example to prepare these reports. Figure 4 presents all the information regarding a bridge construction in process. By using the basic three variables - Budget Cost of Work Scheduled (BCWS), Budget Cost of Work Performed (BCWP) and Actual Cost of Work Performed (ACWP) - it calculates the Schedule Variance (SV) and the Cost Variance (CV) and schedule and cost indices of this specific structure. EV analysis is presented in the current report, showing itself as an objective and valuable tool to accurately compute cost. Estimate at Completion (EAC) is the conventional Earned Value Management methodology with associated Cost Performance Index (CPI) and Schedule Performance Index (SPI) (Narbaev and Marco, 2011).

MAIN REPORT

Print Date: 7/20/2012
Last Import Date:

PROJECT:	AW3	AW3	Real Direct Cost: 2,187,314.96
SUBPROJECT:	AW3.04B	AW3.04B	
G.U.:	AW3.04B.25N	25N	Total Value: 2,621,685.51
CATEGORY :	AW3.04B.25N.B11	Bridges	
SUBCATEGORY:	AW3.04B.25N.B11.01	Bridges	
STRACTURE:	AW3.04B.25N.B11.01	Bridges	

BCWS (budget cost of work scheduled)		77.20 %	1,688,607.15
BCWP (budget cost of work performed		66.68 %	1,458,501.62
ACWP (actual cost of work performed)		66.68 %	2,130,340.72
SCHEDULE VARIANCE	SV		-230,105.53
SCHEDULE VAR %	SV%		-13.63%
SCHEDULE PERFORMANCE INDEX	SPI		0.86
COST VARIANCE CV	CV		-671,839.11
COST VAR %	CV%		-46.06%
COST PERFORMANCE INDEX	CPI		0.68
BAC (BUDGET AT COMPLETION)		100 %	2,187,314.96
EAC (ESTIMATION IN COMPLETION)			3,194,872.11
VAC(VARIANCE AT COMPLETION)			-1,007,557.15
Cost Schedule Index-CSI			0.59
TO COMPLETE COST PERFORMANCE INDEX			12.79

BCWS : BUDGET COST OF WORK SHCEDULED
BCWP : BUDGET COST OF WORK PERFORMED
ACWP : BUDGET COST OF WORK PERFORMED
SV : SCHEDULE VARIANCE
SV% : SCHEDULE VARIANCE
SP : SCHEDULE PERFORMANCE INDEX
CV : COST VARIANCE
CV% : COST VARIANCE %
CPI : COST PERFORMANCE INDEX
BAC : BUDGET AT COMPLETION
VAC : VARIANCE AT COMPLETION
EAC : ESTIMATION AT COMPLETION
CSI : COST SCHEDULE INDEX
TCSPI :TO COMPLETE SCHEDULE PERFORMANCE INDEX
TCCPI : TO COMPLETE COST PERFORMANCE INDEX

Figure 5.33: Earned Value Main Report-SV, CV and EAC Calculations-CPI and SPI indices (Source: Author's proposal)

The CPI and CSI are the indices which indicate the schedule status and the cost status. Any value below 1 means the project is over budget and behind schedule. Even though, nowadays, these parameters might be thought very useful, some other indices have been found to be important to project managers and need to be reported. The first is the TCSPI (To complete schedule performance index) which provides the effort needed to recover the project and put it on track and, finally, what is needed to complete it on schedule.

The second index is the TCCPI (To complete cost performance index) which indicates the effort needed to complete the project within the budget scheduled.

EAC (estimation to completion) is the factor where, if no effort is made to recover the project, the result will be as calculated using the EAC formula.

Some other information that this main report presents are the real direct cost, which is the actual cost at the time of control, and the budget cost, which is derived from the budgeting environment. Both values are important in indices calculations.

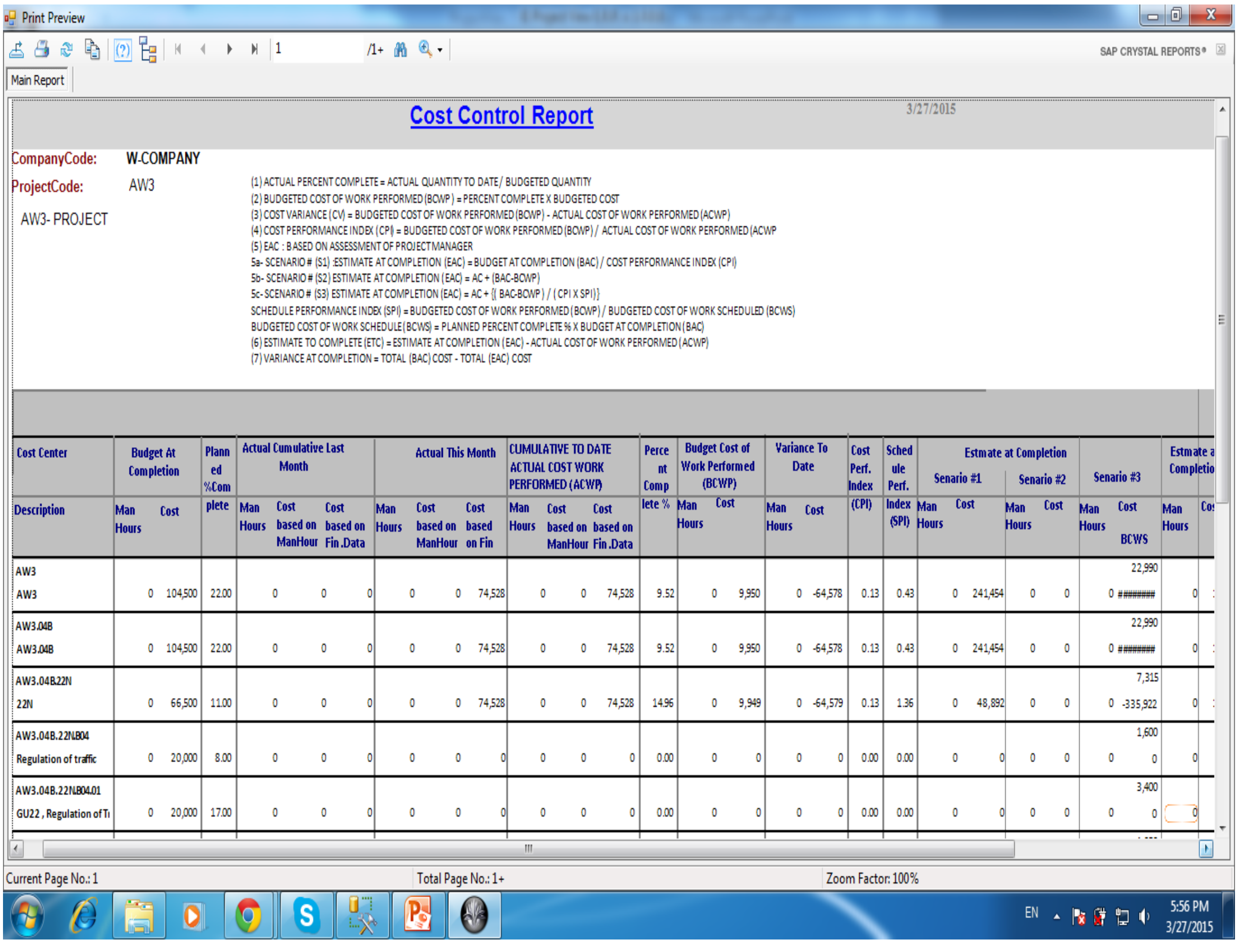
Figure 5.34 is the sum report of analytical basic costing categories' reports which provides split information for the five basic cost categories. This tool is very helpful for project managers to control specific categories of cost, e.g., concrete, subcontractors, reinforcement, and more, and providing information for corrective action during the construction period. It is worth mentioning that this actual cost analysis could be extracted for one structure or the whole project or a package of activities within an area. Information regarding which of those five cost categories has exceeded the budget scheduled is automatically generated.

Actual Cost Analysis

Budget Amount: AW3.04B.25N.B11.01. B265 62+557 KRATHIS,RL
2,187,314.96 Complete %: 97.40

Cost Categories		Weight Factor	Total Cost
01	GENERAL EXPENSES/RUNNING COST	8.91 %	189,829.83
02	MATERIAL	45.46 %	968,372.85
03	PERSONNEL	5.11 %	108,776.65
04	PLANT	14.48 %	308,445.12
05	SUBCONTRACTORS	26.05 %	554,916.27
	Grand Totals:		2,130,340.72

Figure 5.34: Sum-Report: Five Basic Cost Categories-Actual Cost
(Source: Author's proposal)



Print Preview

SAP CRYSTAL REPORTS®

Main Report

Cost Control Report 3/27/2015

CompanyCode: W-COMPANY

ProjectCode: AW3

AW3- PROJECT

(1) ACTUAL PERCENT COMPLETE = ACTUAL QUANTITY TO DATE/ BUDGETED QUANTITY
(2) BUDGETED COST OF WORK PERFORMED (BCWP) = PERCENT COMPLETE X BUDGETED COST
(3) COST VARIANCE (CV) = BUDGETED COST OF WORK PERFORMED (BCWP) - ACTUAL COST OF WORK PERFORMED (ACWP)
(4) COST PERFORMANCE INDEX (CPI) = BUDGETED COST OF WORK PERFORMED (BCWP) / ACTUAL COST OF WORK PERFORMED (ACWP
(5) EAC : BASED ON ASSESSMENT OF PROJECT MANAGER
5a- SCENARIO # (S1) :ESTIMATE AT COMPLETION (EAC) = BUDGET AT COMPLETION (BAC) / COST PERFORMANCE INDEX (CPI)
5b- SCENARIO # (S2) ESTIMATE AT COMPLETION (EAC) = AC + (BAC-BCWP)
5c- SCENARIO # (S3) ESTIMATE AT COMPLETION (EAC) = AC + {(BAC-BCWP) / (CPI X SPI)}
SCHEDULE PERFORMANCE INDEX (SPI) = BUDGETED COST OF WORK PERFORMED (BCWP) / BUDGETED COST OF WORK SCHEDULED (BCWS)
BUDGETED COST OF WORK SCHEDULE (BCWS) = PLANNED PERCENT COMPLETE % X BUDGET AT COMPLETION (BAC)
(6) ESTIMATE TO COMPLETE (ETC) = ESTIMATE AT COMPLETION (EAC) - ACTUAL COST OF WORK PERFORMED (ACWP)
(7) VARIANCE AT COMPLETION = TOTAL (BAC) COST - TOTAL (EAC) COST

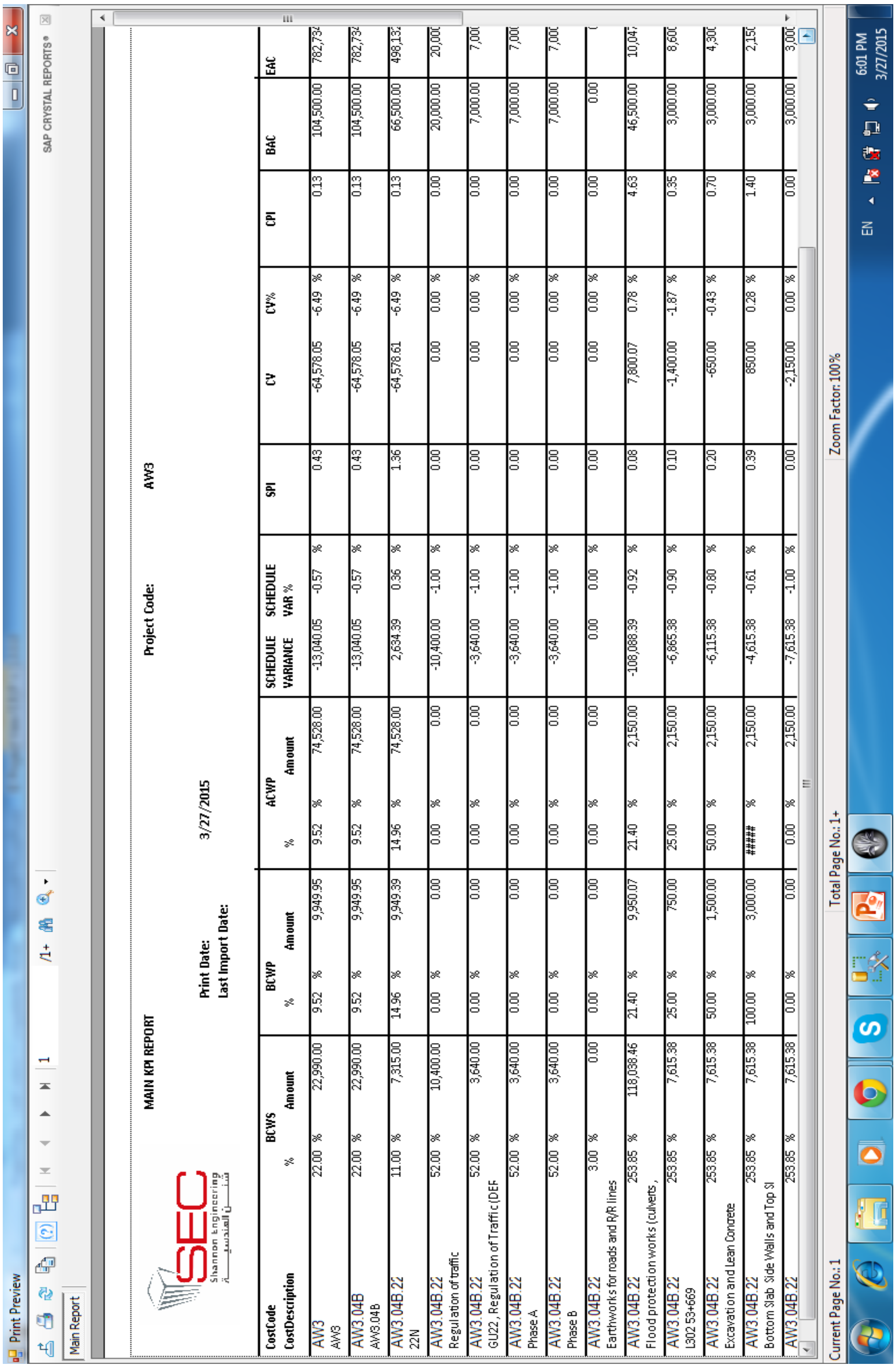
Cost Center	Budget At Completion		Planned %Complete	Actual Cumulative Last Month			Actual This Month			CUMULATIVE TO DATE ACTUAL COST WORK PERFORMED (ACWP)			Percent Complete %	Budget Cost of Work Performed (BCWP)		Variance To Date		Cost Perf. Index (CPI)	Schedule Perf. Index (SPI)	Estmate at Completion							Estmate at Completio	
																				Senario #1		Senario #2		Senario #3				
Description	Man Hours	Cost		Man Hours	Cost based on ManHour	Cost based on Fin .Data	Man Hours	Cost based on ManHour	Cost based on Fin	Man Hours	Cost based on ManHour	Cost based on Fin .Data		Man Hours	Cost	Man Hours	Cost			Man Hours	Cost	Man Hours	Cost	Man Hours	Cost	BCWS	Man Hours	Cos
AW3 AW3	0	104,500	22.00	0	0	0	0	0	74,528	0	0	74,528	9.52	0	9,950	0	-64,578	0.13	0.43	0	241,454	0	0	0	########	22,990	0	
AW3.04B AW3.04B	0	104,500	22.00	0	0	0	0	0	74,528	0	0	74,528	9.52	0	9,950	0	-64,578	0.13	0.43	0	241,454	0	0	0	########	22,990	0	
AW3.04B.22N 22N	0	66,500	11.00	0	0	0	0	0	74,528	0	0	74,528	14.96	0	9,949	0	-64,579	0.13	1.36	0	48,892	0	0	0	-335,922	7,315	0	
AW3.04B.22N.B04 Regulation of traffic	0	20,000	8.00	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0.00	0.00	0	0	0	0	0	0	1,600	0	
AW3.04B.22N.B04.01 GU22 , Regulation of Ti	0	20,000	17.00	0	0	0	0	0	0	0	0	0	0.00	0	0	0	0	0.00	0.00	0	0	0	0	0	0	3,400	0	

Current Page No.: 1 Total Page No.: 1+ Zoom Factor: 100%

EN 5:56 PM 3/27/2015

Figure 5.35: Cost Control Report Layout one (Source: Author's proposal)

Figure 5.35 represents another format of cost control reports with emphasis on different scenarios of the EAC calculations, optimistic, realistic and pessimistic scenarios. No matter which format is chosen, both calculations are the same and provide the same information to managers. This horizontal presentation provides all the current information regarding a specific structure or any other upper level in the project or the project unit. There is always reference to the indices as in previous cost control main reports so any manager who is not familiar with those terms can understand them without delay. Special attention is given to man hours in this report, which provide the effort needed to produce this cost.



CostCode / CostDescription	BCWS %	BCWS Amount	BCWP %	BCWP Amount	ACWP %	ACWP Amount	SCHEDULE VARIANCE	SCHEDULE VAR %	SPI	CV	CV%	CPI	BAC	EAC
AW3 / AW3	22.00 %	22,990.00	9.52 %	9,949.95	9.52 %	74,528.00	-13,040.05	-0.57 %	0.43	-64,578.05	-6.49 %	0.13	104,500.00	782,73
AW3.04B / AW3.04B	22.00 %	22,990.00	9.52 %	9,949.95	9.52 %	74,528.00	-13,040.05	-0.57 %	0.43	-64,578.05	-6.49 %	0.13	104,500.00	782,73
AW3.04B.22 / 22N	11.00 %	7,315.00	14.96 %	9,949.39	14.96 %	74,528.00	2,634.39	0.36 %	1.36	-64,578.61	-6.49 %	0.13	66,500.00	498,13
AW3.04B.22 / Regulation of traffic	52.00 %	10,400.00	0.00 %	0.00	0.00 %	0.00	-10,400.00	-1.00 %	0.00	0.00	0.00 %	0.00	20,000.00	20,00
AW3.04B.22 / GU22, Regulation of Traffic (DEF	52.00 %	3,640.00	0.00 %	0.00	0.00 %	0.00	-3,640.00	-1.00 %	0.00	0.00	0.00 %	0.00	7,000.00	7,00
AW3.04B.22 / Phase A	52.00 %	3,640.00	0.00 %	0.00	0.00 %	0.00	-3,640.00	-1.00 %	0.00	0.00	0.00 %	0.00	7,000.00	7,00
AW3.04B.22 / Phase B	52.00 %	3,640.00	0.00 %	0.00	0.00 %	0.00	-3,640.00	-1.00 %	0.00	0.00	0.00 %	0.00	7,000.00	7,00
AW3.04B.22 / Earthworks for roads and R/R lines	3.00 %	0.00	0.00 %	0.00	0.00 %	0.00	0.00	0.00 %	0.00	0.00	0.00 %	0.00	0.00	
AW3.04B.22 / Flood protection works (culverts ,	253.85 %	118,038.46	21.40 %	9,950.07	21.40 %	2,150.00	-108,088.39	-0.92 %	0.08	7,800.07	0.78 %	4.63	46,500.00	10,04
AW3.04B.22 / L302 53+669	253.85 %	7,615.38	25.00 %	750.00	25.00 %	2,150.00	-6,865.38	-0.90 %	0.10	-1,400.00	-1.87 %	0.35	3,000.00	8,60
AW3.04B.22 / Excavation and Lean Concrete	253.85 %	7,615.38	50.00 %	1,500.00	50.00 %	2,150.00	-6,115.38	-0.80 %	0.20	-650.00	-0.43 %	0.70	3,000.00	4,30
AW3.04B.22 / Bottom Slab Side Walls and Top Sl	253.85 %	7,615.38	100.00 %	3,000.00	##### %	2,150.00	-4,615.38	-0.61 %	0.39	850.00	0.28 %	1.40	3,000.00	2,15
AW3.04B.22	253.85 %	7,615.38	0.00 %	0.00	0.00 %	2,150.00	-7,615.38	-1.00 %	0.00	-2,150.00	0.00 %	0.00	3,000.00	3,00

Figure 5.36: Cost Control Report Layout two (Source: Author's proposal)

Figure 5.36 is a more recent presentation of the figure 4 main report. As can be seen, all variables in calculation indices are presented horizontally so the manager can investigate and check more than one activity. Of course, this process includes more than one format, and in the future more will be prepared for the user's convenience.

5.7.4 STAGE TWO INFERENCES

This second stage is the implementation stage of a complete integrated cost management system development in a project delivery. A successful alpha version of an applied cost management model has been developed. The integration process between the planning and control stages, through the IS model, is a helpful tool to derive valuable reports for the project managers and directors during the construction period, allowing corrective action to put the project back on track. The system will be tested in ongoing various projects and the results will be compared and used to prepare the final version of the integrated cost management system. The application of the system aims to maximize the performance of the proposed integrated system and also be used as feedback for further corrections. The integration process will be expanded into more components and more project factors by keeping the WBS as a dominant factor of transferring information from the planning process to control process.

5.8 PARAMETERIZATION AND SYSTEM APPLICATION-INTEGRATED COST MANAGEMENT SYSTEM AND APPLICATION: STAGE THREE

In stages one and two, the importance of the method used to be precise enough to provide the basis for controlling and monitoring the projects was emphasised . A good budget should be supported by established design parameters and quality levels and then priced on a conceptual basis in enough detail to allow the control process to be effective (Theodorakopoulos, 2009).

Since the system application has been developed, the current stage focuses on matching the system components to the project stages and packages, and presents the results to a report system through the initial developed model. This is a common practice and need that identifies each project's specific characteristics and unique conditions during its implementation. Limitations and drawbacks allow for feedback in the cost management system procedure. The feedback is allowed in all the stages of the cost management and all the stages of the system development through the integration channels that have set up in previous stages.

The time process of developing a prototype cost management model has been previously described and analyzed. In the previous analysis, an alpha prototype version of the integrated system has been developed with emphasis on a unique ID coding system for each project activity. The IS development, which has been previously analyzed, provided all the necessary tools to parameterize the system into many project categories according to their needs and meeting their project targets. At the current stage, after the successful first cost management system version, the model parameterization and the application process is described, as shown in Figure 5.37.

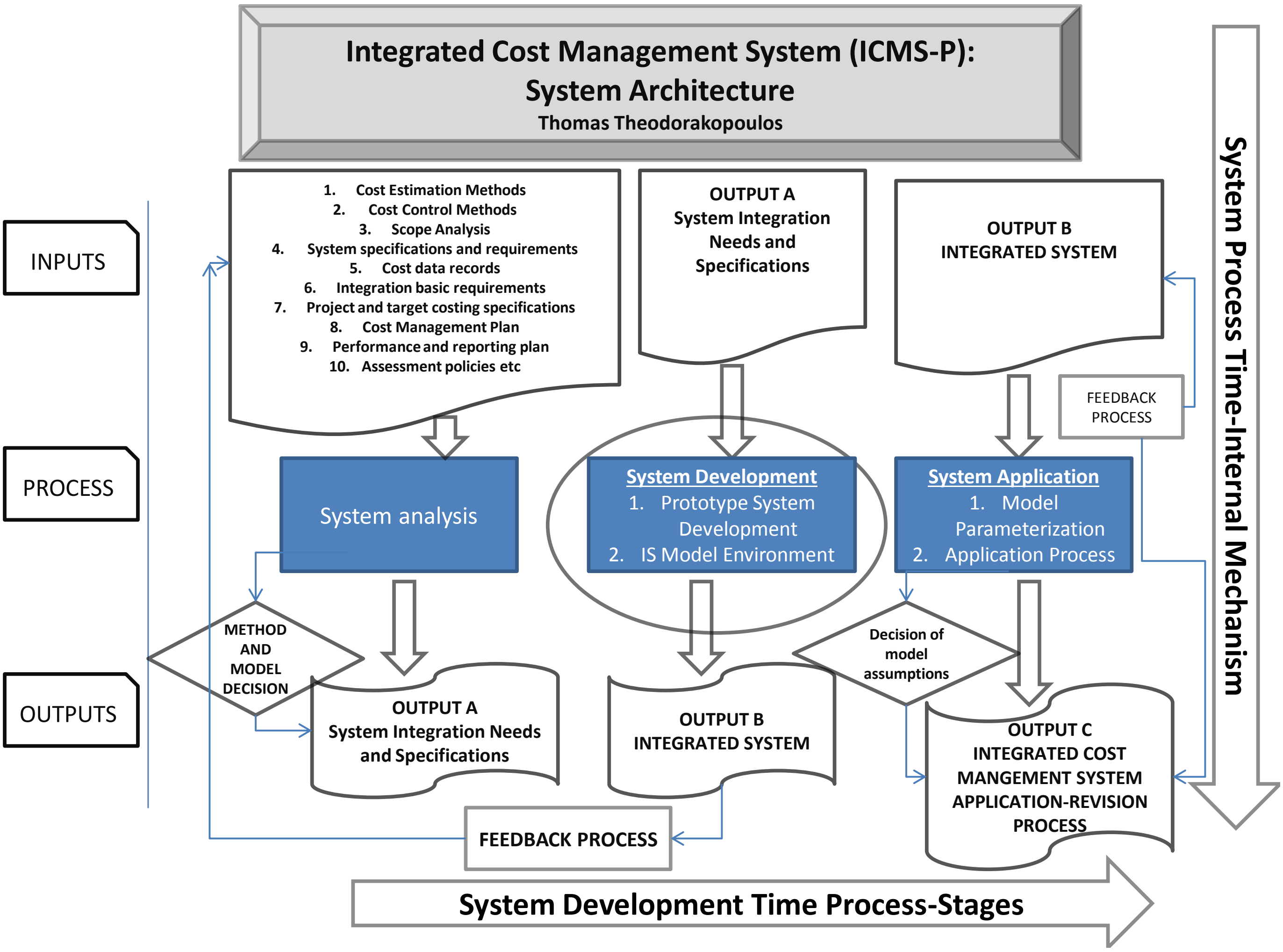
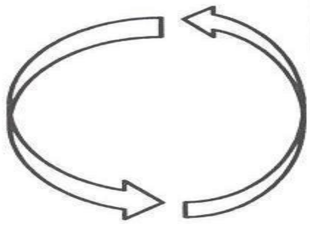


Figure 5.37: System Development Time Process Step 3 (Source: Author's proposal)

Table 5.10: Parameterisation and Application to Bridge Construction (Source: Author's proposal)

Parametarization Process and Application		
Cost Estimation output	**Cost Budgeting**	**Cost Control**
Activity Cost estimation (detail)	**Baseline Cost-WBS**	**Project management plan**
Hydraulic and static Designs PUO-reallocation/ Drainage, power supply grid Expropriation procedures and areas of interest Earth Mass Haul Diagram/ Earthworks transportation/Time-Location Diagram Approvals- Public and Civil Services approvals/document control Quantity Surveying/ per Bridge contstruaction section-Deck, Piles Pilecap etc. etc.	Activity cost plan-Activity budget analysis Respources plan- allocation of resources Requested changes-Mainly in designs or resources plan Cost management detail plan 	Performance measurments-indices and report system Forecasted projections- Cost based on plan schedule Corrective action plan Feedback information

This process defines in a specific way what factors, as shown in Table 5.1 Integration Linkages, are followed in each single project stage. Table 5.12 illustrates an example of integrated factors used for the Bridge Construction, where specific factors have been integrated to provide specific outputs in each cost management stage. These factors have been developed through a close investigation of the real problems related to constructing a specific bridge under unique conditions. The parameterization process matches the real conditions with the selected methods and processes of the system. These requirements and outcomes represent the real conditions of what the contractor or the client will deal with during the project stages.

Dealing with these factors, we are able to get a better projection of reality and provide to the managers a useful action plan to proceed in the construction.

It is extremely important to parameterize all those factors affecting the construction (in this example, the bridge construction) in order to create a more complete integrated system before we proceed to execute the system and the model before any project starts.

Since it is not possible to cover and include all the factors for all the activities for a project, a very characteristic example of infrastructure project was chosen for research purposes. The factors are shown in Table 5.12, and include factors taken into consideration for the estimation and budgeting of the project and for the cost control policy.

When parameterization takes place, the contractor or the client must deal with those factors. The question of how users will deal with the system, it will be clarified through a guideline given later in the chapter. The factors have been divided into three sections, one for each specific stage that any project staff must be aware of. Each factor is presented within the system by a weight factor in each stage according to its effect on the structure budgeting or structure control.

Hydraulic and static designs: Usually the hydraulic and static designs should be completed by that stage. If not the project team needs to run the process faster due to the high importance of that factor, especially for a bridge.

PUO-reallocation/ Drainage, power supply grid: Reallocation and transfer of PUO supplies is valid to be completed as soon as possible otherwise that factor will affect the cost of the bridge construction. Usually all permissions need to be completed and executed before the construction stage.

Expropriation procedures and areas of interest: Equally important, if not more, is the land expropriation, especially in structures like bridges where rivers need to be delivered to the contractors' control for the bridge construction.

Earth Mass Haul Diagram/ Earthworks transportation/Time-Location Diagram: This factor of earthworks and analysis of cuts and fills (see Appendix 21 of mass haul diagram), is of extremely high importance by that stage due to the fact it must be established whether the earthworks are balanced within the project or not. Possibly, extra material will lead to extra estimation cost and this usually is a contractors' risk that must be taken.

Approvals- Public and civil Service approvals/document control: Approvals of civil services are needed in the stage prior to bridge construction. Sometimes, and it is quite often, old bridges are demolished to construct a new one in the same place. Demolition procedures are time-consuming and extra permission is needed. This factor affects time and the cost of the bridge construction.

Quantity Surveying/ per Bridge Construction Section-Deck, Piles Pile Cap and more: Quantity surveying is based on analytical design, and even though it is common to have it in that early stage, unfortunately no special attention is given to providing a detailed table with quantities. Late quantity surveying production leads to cost overruns.

Activity cost Plan-Activity budget analysis: In the budgeting stage, an important factor which has to be considered is the cost plan of each specific activity of the bridge. This detailed analysis is the second phase of the previously mentioned estimation factor.

Resources plan - allocation of resources: Allocation of resources must be prepared in that stage without delay. All resources from staff, labor, engineers is defined and prepared. That factor is vital and can be revised in the control process accordingly. If it is not well prepared, it is quite certain that it will cause delay and extra cost.

Requested Changes -Mainly in designs or resources plan: A useful approach for managers is to set up the factor of changes in the budgeting stage. This document and analysis save time in the control stage, and if carefully prepared in the budgeting stage, will support the bridge construction process if any changes occur.

Cost management detail plan: The detail cost management plan is the dominant factor for a manager. It indicates to him if the preparation has been adequate and what he has to expect in the future. Usually, it reflects all those grey zones that may affect the cost and timing of the bridge construction. It starts with demolition cost, then adds in piles and pilecap and finishes with abutments and piers and, of course, the deck slab. If all these construction phases are adequately estimated and prepared, this factor becomes the most useful tool for the manager.

Performance Measurements-Indices and report system: The reporting system is usually developed for the whole project without exceptions. Reports are kept as simple as possible, but sometimes in special structures, extra control is needed. In a bridge construction, a specific time warning is provided in each specific stage. This warning automatically informs the manager to analyze the data of the current stage under construction and make suggestions if any delay or extra cost occurred. These suggestions are specific scenarios indicating extra shifts on piers or deck slab, extra pile machines if the ground surface of the river is unstable and causes delays, or the weather forecasts mention heavy rain that will raise the river surface. This factor is one of the most creative and the integrated system includes many corrective actions as decision making policy. For that reason, this factor is a very helpful tool in managing the process of bridge construction

Forecasted projections- Cost based on plan schedule: These factors of projections and forecast calculations mainly are used in the reports of the total reporting system. Beyond that, the bridge may have intermediate forecasted projections due to long time construction stages. The integrated system could be asked to project results when the piles have been completed and before the pile cap starts.

Corrective action plan: this is a major factor and special consideration must be given in this documentation because it affects the whole process of construction. The integrated cost management system provides suggestions with all corrective plans and actions regarding the issues of the bridge construction and according to preparation that has been made in previous stages, as explained before.

Feedback information: It would not be a fully integrated cost management system if no feedback information is involved in that process. Feedback information factor and how easy or not information can be transferred within the process then becomes a serious issue. Without any smooth transfer of information from one stage to the other and vice versa, information is not distributed to the members of the project, and valuable time will be lost, hence cost will be increased.

As shown in Table 5.12, the application process involves feedback in all stages and corrective actions which will support the construction.

5.8.1 STAGE THREE INFERENCES

This stage is the implementation stage of a complete integrated cost management System application (Figure 5.35) and same time the initial stage of application and parameterization in a project package such as a Bridge Construction Cost Management Process.

A successful real application of the system developed has been analyzed and the results from the main reports will be used as feedback for further applications within the project. The valuable information which is derived from those reports has been used in real time construction to avoid further budget failures and corrective actions have been used to minimize the budget negative variance before the completion of the Bridge Construction.

The application and parameterization will be expanded in more project packages and all the results will be synthesized in the total project management procedures. The application model aims to maximize the performance of the proposed model and the integration process will be expanded to more components and more project factors by keeping WBS as a dominant factor of transferring information from the planning process to the control process.

With the completion of the system development and the presentation of the environment of budgeting and actual cost, together with the reporting system as it appears in this chapter, the integrated system is verified for its function usage. The results and calculations presented provide adequate verification of the system and the model, and how this is applied in real projects. The results and indices that are produced through calculations are valid, and their validity appears also in the case studies.

5.9 GUIDELINES FOR SYSTEM USE AND USERS

After completing the analysis of the three stage development of the integrated cost management system and its application, it is useful to produce a guide to support the users and the managers in how to implement and how to drive this integrated system in their projects. It is also a guide for the clients and the contractors who are willing to include integration processes in their way of implementing projects.

The ICMS-P is system is developed in stages, and these stages are recycled and repeated in the four cost management stages through the dynamic process of integration. Hence, it is not a static procedure with precise job descriptions. For research purposes, the guide is provided, calling the stages as Milestones, and is available for users and participants.

Milestone No1: Framework of requirements. It is necessary to establish the appropriate framework according to the nature of the project. The guide of requirements that is provided in the chapter is useful for defining one more tailored to the uniqueness and the nature of each individual project. The initial framework of methods and requirements must be made by the upper management, which decides the policy and what methodology it wants to use in the project’s implementation. To establish this, a team of the following positions is needed to proceed with a more detailed framework and documentation regarding an integration policy.

Milestone No2: Detail Framework of requirements. In this milestone a list of items and requirements will be defined for each of the cost management stages. According to the nature of the project, a team comprised of the project manager, project control manager, Quantity Surveyor, and others such as a Geotechnical Engineer, Design Engineer and Contract Manager, must decide, through the proposed channels of the Integration System, the methods, the input and the desirable results of the system that will be followed.

Milestone No3: System Analysis and Integration Process. This milestone defines the levels of integration and the PIS Environment that this system will use. The proposed ICMS-P provides all the relevant information to set up these parameters to the needs of the project and the managers. The Integration procedures that it offers helps the team described in milestone 2 to understand the linkages and correct any problems occurring in that stage. The integration process depends on the various factors that have already been described in all three stages of the system development, plus more that can be generated according to the project demands. In milestone No3, the team must include the Head who will be the Project Control Manager, or a position with a similar role. The rest of the team will be comprised of people with different expertise, like a Quality Manager for the documents, a Time Scheduler, a Cost Controller, a Mechanical and Electrical Engineer, an IT engineer for the PIS Environment development, and a sub team of users whose job starts in milestone No4 with entry requirements and project report results assessment and projections. The current team will be responsible for any parameterization needed in the last stages of the system when the unique factors of configuration must be prepared before proceeding to compare the planning and control stage.

Milestone No4: This milestone is mainly related to the final use of the system on a daily basis. The team that uses and deals with the daily issues of the system is responsible for the entries at the construction site and how they are presented in the stages development of the system. Furthermore, the team is responsible for the documents and the design revision and any variance of the planning stage that must be recorded. The reporting system must be addressed and assessed before it is given to the upper management, and any suggestions for decision making policy must also be initially evaluated by the control managers.

5.10 CONTRIBUTION OF INTEGRATED COST MANAGEMENT SYSTEM TO PROJECT DELIVERY PROCESS

The new integrated cost management system that is proposed in this research and which supports the decision making at any stage of a project is a valid guide for all project managers and upper management within companies.

As has been shown, this system is:

- A powerful tool for policy. It helps Project managers to establish a policy to manage their projects more efficiently.
- Fully able to integrate all information generated from the design to control stage, with feedback.
- Effective in providing a simulation of the outcome through a route/path of decisions which need to be taken at specific times and parts of the project and which will lead to a certain result if followed.
- Providing all possible solutions to problems after an evaluation of any variance of initial planning targets.
- Enabling project managers to control all aspects of the process and allowing involvement.

The significance of the ICMS-P and the innovatory nature of the system is discussed in Chapter seven, along with the benefits that it offers to the construction industry.

5.11 ICMS-P DEVELOPMENT INFERENCES

The ICMS-P has been developed and all the sub- packages of the system have been fully explained and described.

The system concept is the main description that covers all the stages of the integrated system, describing the mechanism of the integration system. As was expected, there was a necessity to include within the system development a complete PIS process and environment, which is the framework and the database where the integration system should be included and applied.

PIS combines all the operational and construction activities in a unified process of managing projects. PIS helped to organize the extended information generated in projects. PIS aspects related to the project such as budgeting, procurement, risk assessment, site monitoring, project cost reports and a wide range of reports and figures have been defined and coded within an integrated procedure. With the PIS application is provided a clear understanding of the design of the integrated system, in a readable and understandable way. WBS structure is the key factor in managing the structure of the project. WBS also includes the hierarchical structure in levels. Using the PIS, it is expected a step further closer to the automation in construction will be achieved, but also a useful tool for decision making policy throughout a project's life cycle will have been developed.

The proposed integrated cost management system has been developed mainly to estimate and manage the cost of any project and any project activity, and to verify the truth of this simulation of cost through the integration process that has been described.

The framework of requirements supports the project at all stages from inception to completion, designing the resources or elements, cost estimation, budgeting and cost control. The importance of the development of the integrated system is that all the inputs, outputs and techniques are being described and analyzed in the integration dynamic process. Each output of the package becomes input to the next stage of the system stages.

An example of constructing a slab of a building explains the fundamental characteristics of cost estimation and cost control system. WBS was chosen carefully, same as were the levels of hierarchy. Cost categories and ID codes have been created and finally used to successfully measure and estimate the cost of the slab. Estimating the cost in this example was not the main difficulty in the development of the ICMS-P. The most important issue was the integration and control environment, and how this would become fully comparable with actual values.

A major result in developing the integrated system is the structure of the system design process. It is a matrix flow chart with two main axes. The horizontal axis presents the time process of the system in three main stages: system analysis, system development (prototype) and the system parameterization and application process. The vertical axis is the system process time needed for each stage to be completed. A key factor that makes the system work efficiently is the feedback process within the system, which allows a continuous flow in any stage of project delivery.

To understand adequately the stage one of the system analysis, the estimation and the control process and how these are integrated and connected have been explained. The analysis of EVA provides all the information needed to proceed with the control process development. The examples presented allowed the complete verification how the process works and calculates results. This is an organized way to control the information instead of the traditional approaches, where too much unorganized information was presented to managers, according to Hendrickson (1998), who argued that this can result in confusion and paralysis in decision making.

Since the literature highlights the need to prepare estimates, with an emphasis on managing the cost and use of the information provided in the planning stage to control stage, the integrated system does exactly this process; this allows more time for the planning stage, giving better estimates which allow flexibility and easy control. Common structure in all the stages of the ICMS-P can ensure a reliable comparison of estimated values with actual cost values.

The necessity to provide an alternative in the cost management process is already shown from the first stage of the system analysis and quickly becomes a powerful tool, able to provide information relating to a project's progress in terms of cost and schedule.

The system analysis is the most important stage since it establishes all the requirements to set up the system properly and to be functional. The purpose of identifying as an output all these parameters in order to establish a complete system framework has been achieved. Special emphasis of EVA covers most of the project's needs. The unique ID systems and WBS are the dominant factors in the way project will be controlled and information related to the project can be recalled during the construction stage.

Stage two concerns the system development with an alpha version of the system application, which analyzes the integration processes and then feedbacks from one process to the other. These linkages are described analytically according to the stage of the project. Two main components are involved in the results of stage two; the budgeting cost database and the actual cost database. Both planning and control databases follow the same structured WBS in various levels with a unique ID coding system allowing a full integration process between the budgeting and control stage. To solve the problem of providing information and inputs within the system, various exporting and importing files have been created which support the system with actual data and information.

Various extracted tables and figures are analyzed in terms of viewing opportunities. All cost categories are presented, and all activities and WBS and ID codes are shown in analytical budgeting and actual values. All tables are fully compared with an actual cost environment and their presentation design is fully applicable, with managers' controlling policy using a real-time comparison of actual and budgeting values.

The reporting system is also presented in stage two. Monitoring reports based on EVA are being developed, providing the progress and the performance of the project. Narbaev and Marco (2011) also argued that EV analysis which, through presenting in current reports and research, is showing itself as an objective and valuable tool to accurately compute Estimate at Completion (EAC), the conventional Earned Value Management methodology with associated Cost Performance Index (CPI) and Schedule Performance Index (SPI).

Various presentations of EV analysis provide valuable information, with emphasis on the completed cost estimation, and suggestions for recovery, if needed. Finally, within the second stage, a successful alpha version of an applied cost management system has been developed. The integration process has been achieved.

Since construction of the system has been completed, current stage three focused on matching the system components to the project stages and packages and presenting the results to a reporting system through the developed model.

At stage 3, the parameterization of all the factors affecting the construction (an example is given in the current chapter and in chapter six - case studies) have been described and analyzed. These parameters affect the cost through the whole project delivery life cycle and are managed accordingly. Each factor is represented in the system as a weight factor, and is used while budgeting and while controlling the project. Designs, approvals, relocation of PUO, Hydraulics, and Expropriation procedures are some of those parameters affecting time and cost.

Variations and changes are always calculated and measured from the integrated system, providing suggestions for a decision-making policy and supporting the project delivery.

The development of the integrated system analyzed in the current chapter highlighted the contribution of the Integrated cost management system to the project delivery process. It is a valid guide for all project managers and upper management within companies as it supports decision making in any stage of the project.

Therefore, the system helps managers to establish a policy to manage their projects efficiently; it supports any action to be taken during the project delivery stages; it gives real time indication of project problems and suggestions or proposed solutions; it measures any variance or change occurring in the construction or design stage and integrates it within the system; the valuable information presented by the reporting system avoids further budget failures; simulation of the project outcomes are presented not only through indices, but also through a route/path of decisions that need to be taken at specific times and with specific structures.

Additionally, the system dynamically involves people within the process, helping information to be shared throughout the whole process; consequently, managers can control the staff with less effort. A useful guideline for the system use and the users has been developed and explained so the project manager and the upper management have a clear picture of how the ICMS-P works. It also acts as a guide to all the involved participants of the project, raising awareness of their job descriptions related to the ICMS-P procedures.

Finally, the ICMS-P can be applied to any project stage even though maximum results are gained when applied in early stages. In terms of innovation areas, the integrated cost management system provides a proactive means for project control, and can make cost a driver for design, hence reducing the waste and increasing the value of the project. That means planning and control stages are integrated and share the same goal of maximizing the performance of the project.

5.12 SUMMARY

The current chapter is the main chapter which describes the integrated cost management system (ICMS-P) development.

Initially the context of the new ICMS-P and how it works was described. All variables and parameters have been set up and the framework has been established successfully. The environment of PIS that is needed to make the system works together with the software environment have been analyzed and established. This environment is a structure of the Information System produced for this specific integrated system.

All the stages of the Integration system have been analyzed and established. Stage one is the framework development system, and analysis of that system. Stage two is the alpha version of system development and stage three is the parameterization of the system and the system application. A guideline of the system use and the users that are involved within the process has been developed and provided.

Finally, the contribution of the ICMS-P to the project delivery processes and the findings of the ICMS-P in all the stages developed are described.

CHAPTER SIX: TRIALLING AND VALIDATING THE ICMS-P

6.1 OVERVIEW

This chapter presents cases of how cost is managed in a construction organization regarding a typical river bridge and a motorway underpass. These examples are cases from a real project which followed the proposed Integrated Cost Management System as described in previous chapters, providing the project managers with all the necessary information for decision making to complete these typical constructions. Furthermore, the way in which the integrated system supports the decision making that led to completion of the structure without delay or cost overrun is described. The users' participation in the alpha version of the system which has been narrowed down to fit this specific project and structure is clarified. Additionally, the chapter identifies the contribution of the integrated system to the decision-making process through a real construction case and the contribution of the ICMS-P to Project Delivery processes

6.2 REPORTED STRUCTURE EXAMPLES

The Integrated Cost Management system has been developed to manage and support real structures and projects. The ICMS-P system has already been applied to real structures and in a real project scheme, providing special results and suggested solutions to the managers when needed for decision making.

The ICMS-P had to be tested and analyzed during the project delivery process. For research purposes, two different structures have been chosen as the first approach to providing valid information and testing of the Integrated System. The analysis of the examples is described, together with the user groups and how all participants worked together to achieve the results. The sequence of analysis defines: dimensional information related to the structures, the system's initial set-up, the framework requirements, the integration needs and specifications and how these were developed to a PIS Environment of integration process, the parameterization of most of the aspects which were related to the constructions, the reporting system and measurements required, and finally the execution of the system through the life cycle of the cost management procedures, together with the results and the decision making policy.

These structures are one long span river bridge and a top down structure underpass within an Interchange (I/C) section.

6.3 REPORTED STRUCTURE ONE: RIVER BRIDGE

6.3.1 Dimensional Information and Basic Description of the Bridge Structure

Starting with the framework of requirements and historical data, Project Scope, Description of Elements, Methodology and WBS as required in Table 5.1, Figure 6.1 shows the construction of a typical twin bridge spanning 200m in length with a 12.5 m width for each branch (left branch and right branch).

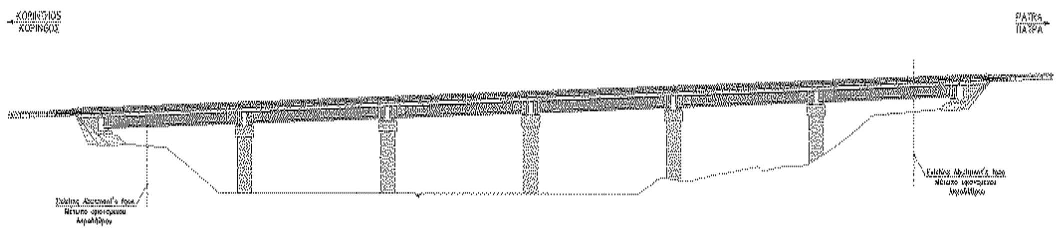


Figure 6.1: RIVER BRIDGE GRAPH (Source: Author's proposal)

As shown in Figure 6.1, the river bridge includes 5 main middle abutments and two side abutments. Total length is almost 200 m and it is a twin bridge, which means two identical bridges connected with a concrete joint.

This twin bridge is an existing bridge of a national motorway carrying traffic, built in the late 1960s.

6.3.2 Initial Framework Requirements in cost management process and Set up of the System

The initial plan was to rehabilitate the old structure by keeping the abutments and reconstructing only the deck slab on the final surface elevation. Based on that specific design, the budget has been set up to include the full replacement of the deck, but not the foundations or columns of the bridge. This Preliminary Design (Appendix 4) was not enough and did not get final approval. In the final design (Appendix 5), the designer, after recommendations, decided to demolish both bridges and replace them by building new ones with wider columns. There is an assessment of the alternative solution described in the framework of requirements. The Estimation of the upper management was taken based on two main parameters: the effort needed to rehabilitate the twin bridge and the unforeseen conditions due to the lack of design and foundation drawings and the additional cost to reinforce the current foundations. The foundation data concerning the old bridge were few because construction took place in late 60s.

The integrated system was used to provide rapidly a new set of project management plans and a budget which allowed for correcting actions or leading actions to be made. The early activities duration was found, based on similar constructions, and the risks and threats of constructing a new bridge were found to be fewer in comparison, and also causing less disruption to the river beds. In that case the plan should lead to a cost budget, including the cost of demolishing the old bridge and replacing it with a brand-new construction.

The schedule and the budget were set based on that decision. The right branch was demolished and a new rise was designed. This information was used to revise the schedule, and the cost and the resources were planned.

In this case the design change did not affect the final plan, but was used to reallocate more efficiently the resources, and measure the results.

Therefore, even when this dramatic change occurred, with the support of the integrated system, all the new parameters of the new bridge were included in the final cost management system.

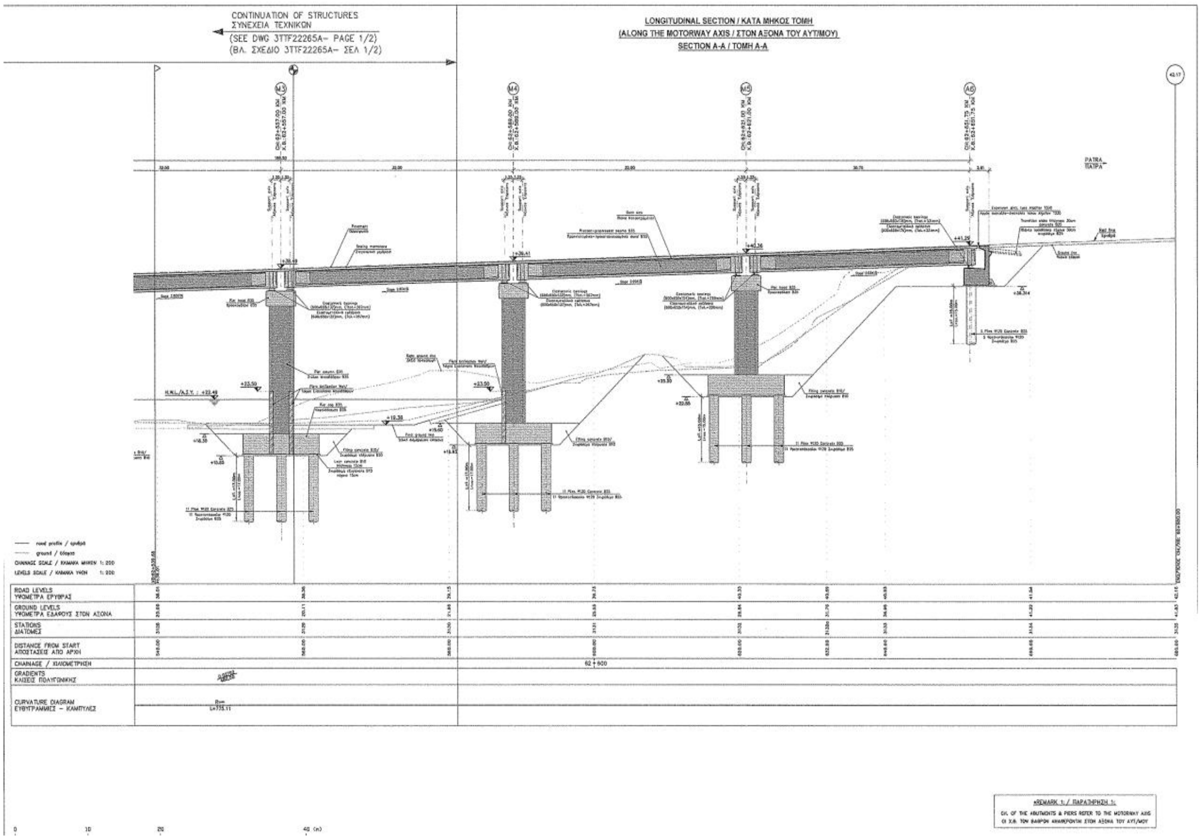


Figure 6.2: RIVER BRIDGE PART A, STRUCTURE PACKAGES (Source: Author's proposal)

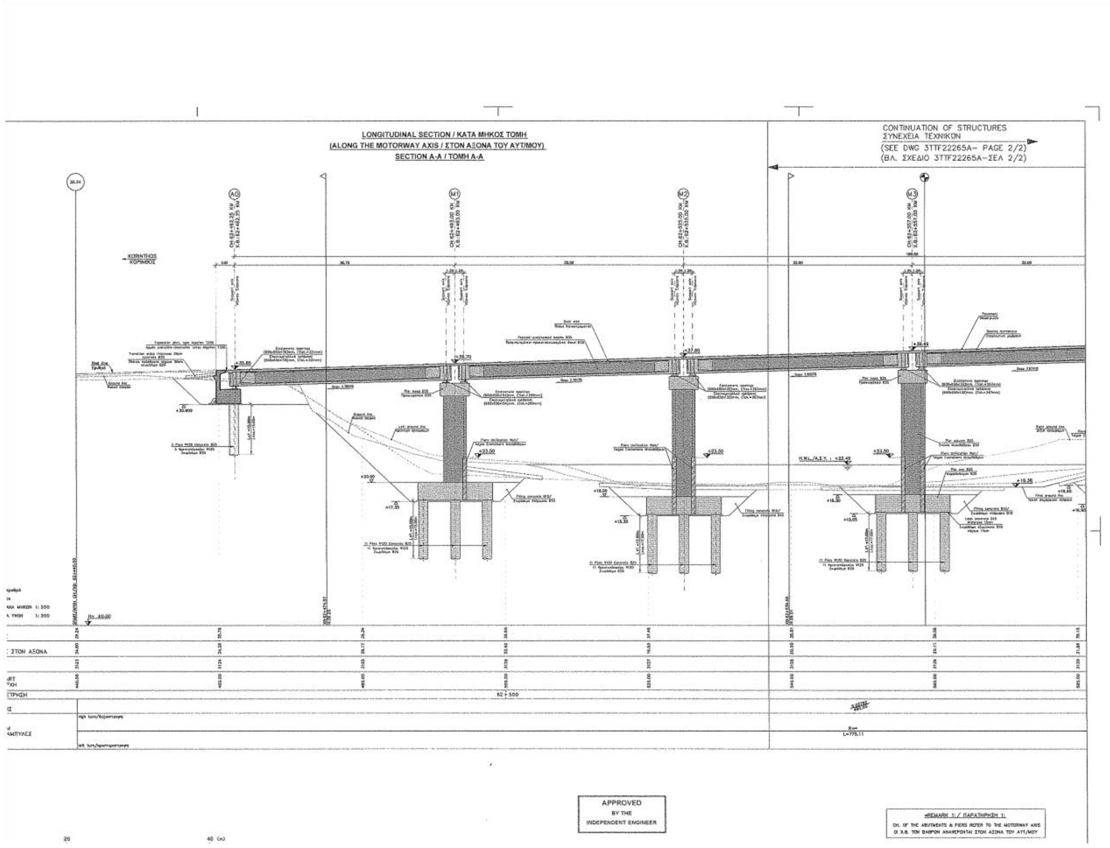


Figure 6.3: RIVER BRIDGE PART B, STRUCTURE PACKAGES (Source: Author's proposal)

Figure 6.2 and 6.3 show the structure stages of the Bridge. The complete structure stages also appear in both Figures as described in the main activities ID, which will be defined later in the WBS of the structure.

Table 6.1: RIVER BRIDGE WBS STRUCTURE (Source: Author's proposal)

BRIDGE RIVER-RL
1. Demolition of Existing Structure
2. Excavation , Piles and Pilecap
3. Abutments and Piers
4. Deck Slab
5. Finishing Works (Deck Slab)
6. Retaining Walls and Approach Embankments

The work method statement indicates in Table 6.1 that first we demolish the existing structure. Then, the main excavations, including transferring the concrete pieces and earthwork material of the existing structure plus excavation material for reforming the river beds should be carried out. After excavations, all the piles and pile caps are constructed, as shown in Figures 6.2 and 6.3. The next stage is the construction of the abutments and piers, before starting the deck slab.

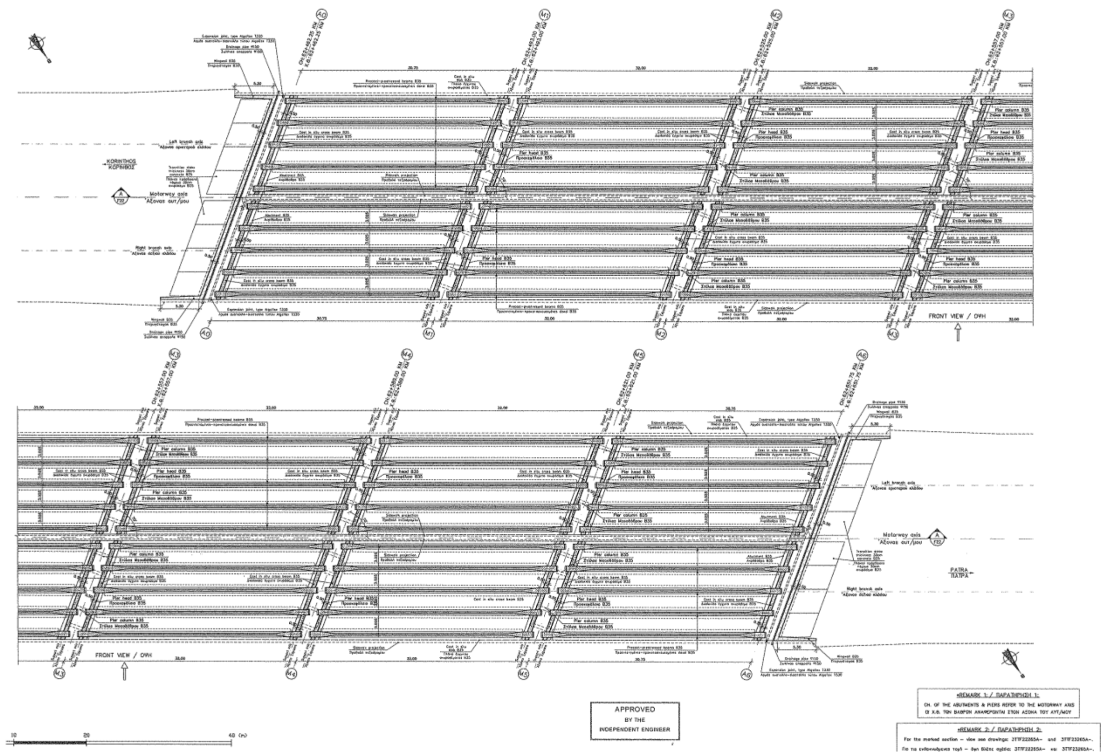


Figure 6.4: RIVER BRIDGE DECK SLAB BEAMS (Source: Author's proposal)

The deck slab involves two different stages: first, the construction and placement of beams; and then concreting the final deck with concrete, as shown in Figure 6.4 and Figure 6.5:

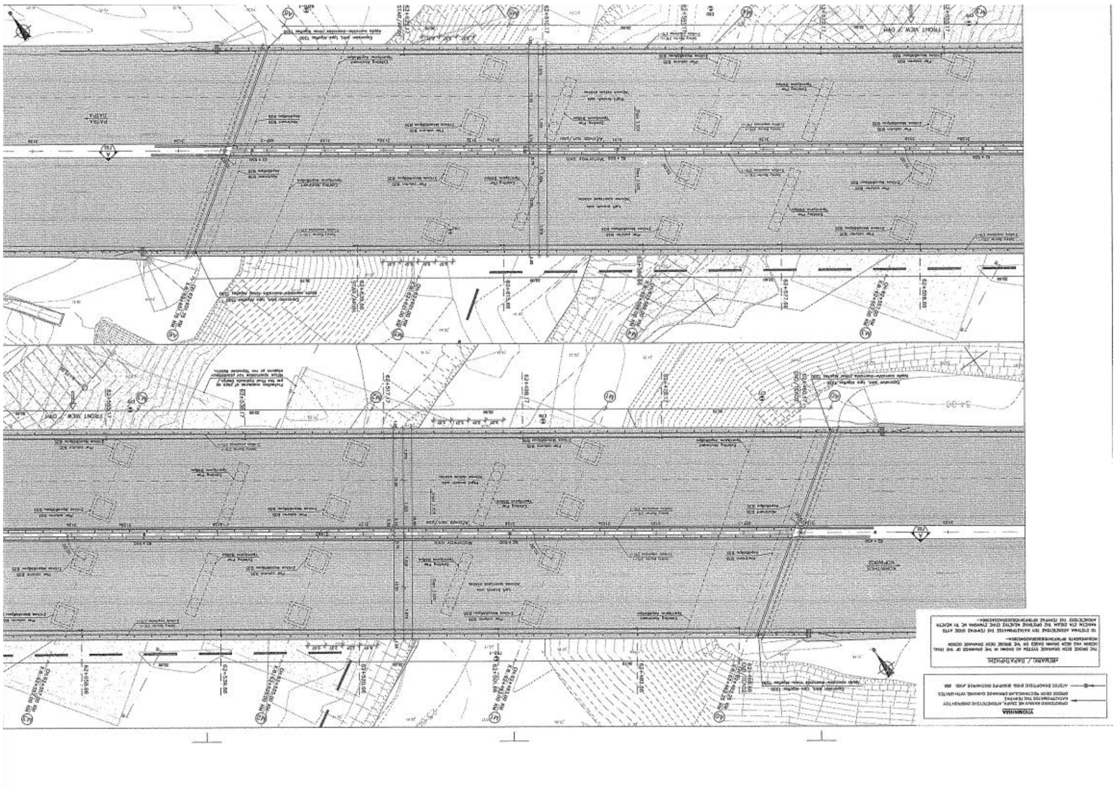


Figure 6.5: RIVER BRIDGE DECK SLAB FINAL CONCRETE SURFACE (Source: Author's proposal)

Based on the final design, and knowing that eventually both bridges will be demolished, all information related to the bridge have been included in the Integrated Cost Management System for budgeting and control. The method followed to set up the process was to establish all the stages of the bridge construction within the integrated system and manage it.

6.3.3 Integration needs and specifications development and a PIS Environment

The team of the current stage mainly consists of the Project Control Manager, Geotechnical Engineer, Structural Engineer, Environmental Engineer, Estimators, Planners and IT Support. At this stage, the requirements and the outcomes are related to the WBS, Schedule Estimating, Staff recruiting, Activity Cost Estimation, Project Calendars, tools and techniques for estimation and management plans and other various documents related to the bridge requirements.

The first task was to establish the coding system specifically for the bridge which would indicate the way it will be controlled.

Table 6.2: WBS-Bridge Coding System (Source: Author's proposal)

CODING SYSTEM-**B11- BRIDGES**				
AWXXX				
4XXX				
	GU		**BK**	**ACTIVITY CODE**
	Bridges		B11	**AW3.04B.25N.B11**
	Bridges		B11.1	**AW3.04B.25N.B11.1**
	BRIDGE -RL	00+XXX	B11.1.07	**AW3.04B.25N.B11.1.07**
	1. Demolition of Existing Structure		B11.1.07.01	**AW3.04B.25N.B11.1.07.0 1**
	2. Excavation , Piles and Pilecap		B11.1.07.02	**AW3.04B.25N.B11.1.07.0 2**
	3. Abutments and Piers		B11.1.07.03	**AW3.04B.25N.B11.1.07.0 3**
	4. Deck Slab		B11.1.07.04	**AW3.04B.25N.B11.1.07.0 4**
	5. Finishing Works (Deck Slab)		B11.1.07.05	**AW3.04B.25N.B11.1.07.0 5**
	6. Retaining Walls and Approach Embankments		B11.1.07.06	**AW3.04B.25N.B11.1.07.0 6**
	BRIDGE -LL	00+XXX	B11.1.08	**AW3.04B.25N.B11.1.08**
	1. Demolition of Existing Structure		B11.1.08.01	**AW3.04B.25N.B11.1.08.0 1**
	2. Excavation , Piles and Pilecap		B11.1.08.02	**AW3.04B.25N.B11.1.08.0 2**
	3. Abutments and Piers		B11.1.08.03	**AW3.04B.25N.B11.1.08.0 3**
	4. Deck Slab		B11.1.08.04	**AW3.04B.25N.B11.1.08.0 4**
	5. Finishing Works (Deck Slab)		B11.1.08.05	**AW3.04B.25N.B11.1.08.0 5**
	6. Retaining Walls and Approach Embankments		B11.1.08.06	**AW3.04B.25N.B11.1.08.0 6**

The Unique ID code allows the relative data and information to be integrated into the estimation and control stage. The current coding system allows direct comparison between actual cost and budgeting cost, but also transfers all the documentation related to the bridge. When a change occurs in the control stage, for example, the system automatically transfers, through the integration process, the information to the estimation environment. Therefore, the comparisons are no longer suboptimal but represent reality, and simulate the estimation process to the real factors and problems when these occur.

Part of the Integration process is to establish an information flow with the relevant documentation throughout the life cycle of the project. For the bridge example, together with the users' group, a series of important lists have been developed that will be used as import when the PIS environment is ready for use. These include among others: a list of items related to the structure, plants, and unique tables of materials, personnel and subcontractors which are related with Table 6.2, the WBS Coding System, connection with primavera or related software, calendars, and design follow- up procedures.

Starting with the design follow- up (Appendix 4 & 5) a methodology of keeping a relevant record of documentation of approvals and comments which are helpful to keep all variances and field of change activities recorded has been established. In the bridge case, the records start from the Preliminary design of rehabilitation and end with the new final design, with a sequence of approvals with or without comments. The Quality Manager and documentation administrator keep the records for relevant usage. Design information, as all information related to the time schedule and resources allocation, is connected with the primavera software for actual control and time variances that affect the construction (Appendix 6).

In the basic list of items (Appendix 7) the items used to construct the bridge are listed. Materials, subcontractors and additional personnel rates are included in this list. Each one is assigned a unique ID code for PIS environment usage. This item list is an example drawn from various different construction projects, and is based on the work method statement and work packages as described already. Once this list is imported to the PIS environment of the Integrated Cost Management System, it is allocated to any of the structure's ID as part of cost and resource allocation.

Appendix 8 provides a record and a table of plants used for the bridge construction. This list explains all the relevant information related to the plant, but also the location of work as part of the calendar process to get information of the usage of each plant separately. This information is also an input of the system, and the Mechanical Engineer onsite, together with the Headquarters Mechanical Engineer are responsible for delivering this information to the ICMS-P.

Appendix 9 and Appendix 10 provide an illustration of a Budget Cost of the bridge and the Actual Cost form based on the WBS. This is important information for the system. The cost has been distributed to the WBS using various methods and tools as parametric estimations, bottom up techniques and ABC methods. The Project Control Manager and Estimators and planners all have the responsibility to deliver those items to the ICMS-P application process.

Due to the importance of time on the sites, and the flexibility to deliver early, the information ICMS-P has developed an innovative system of calendars which allows minimum time to deliver the information. Materials, Personnel, Subcontractors, Plants are allocated directly from the ICMS-P, so before establishing how many hours an employee works, it is already known where he worked without enabled users or other employees having to worry about the nature of his work or the material identification needed to match to the activities. This innovation is described in Figure 5.30, and in Appendix 11, Appendix 12 and Appendix 13 it is noticeable the way the information is distributed. The personnel are being allocated to the WBS of the structure in a weekly program. The same approach is used for the allocation of materials to the structure stages. Finally, the control of Subcontractors becomes more efficient by this method of information distribution. These excel formats are extracted from the system accordingly.

Users no longer need to ask or think about how to match the activities on the site with quantities because the ICMS-P does that. The sheets derived from the system transfer the information through the integration channels so the comparison with budget stage becomes a real comparison based on the same parameters and same assumptions.

The current users group, together with the IT support team, is able now to use the PIS environment and provide important information to the managers. Resource calendars, as described in the framework requirements, have been established successfully, the cost baseline has been already imported to the PIS environment of the ICMS-P and the project schedule is being connected with the unique ID codes of any activity described.

The following day- to- day process relies on the users group consisting of: engineers, accountants or any simple computer skilled employee who has been trained in the ICMS-P rules and specifications.

The PIS environment of the ICMS-P demonstrates two main environments as described in Chapter 5. The budget environment and the actual cost environment are described in tables 6.3 and 6.4

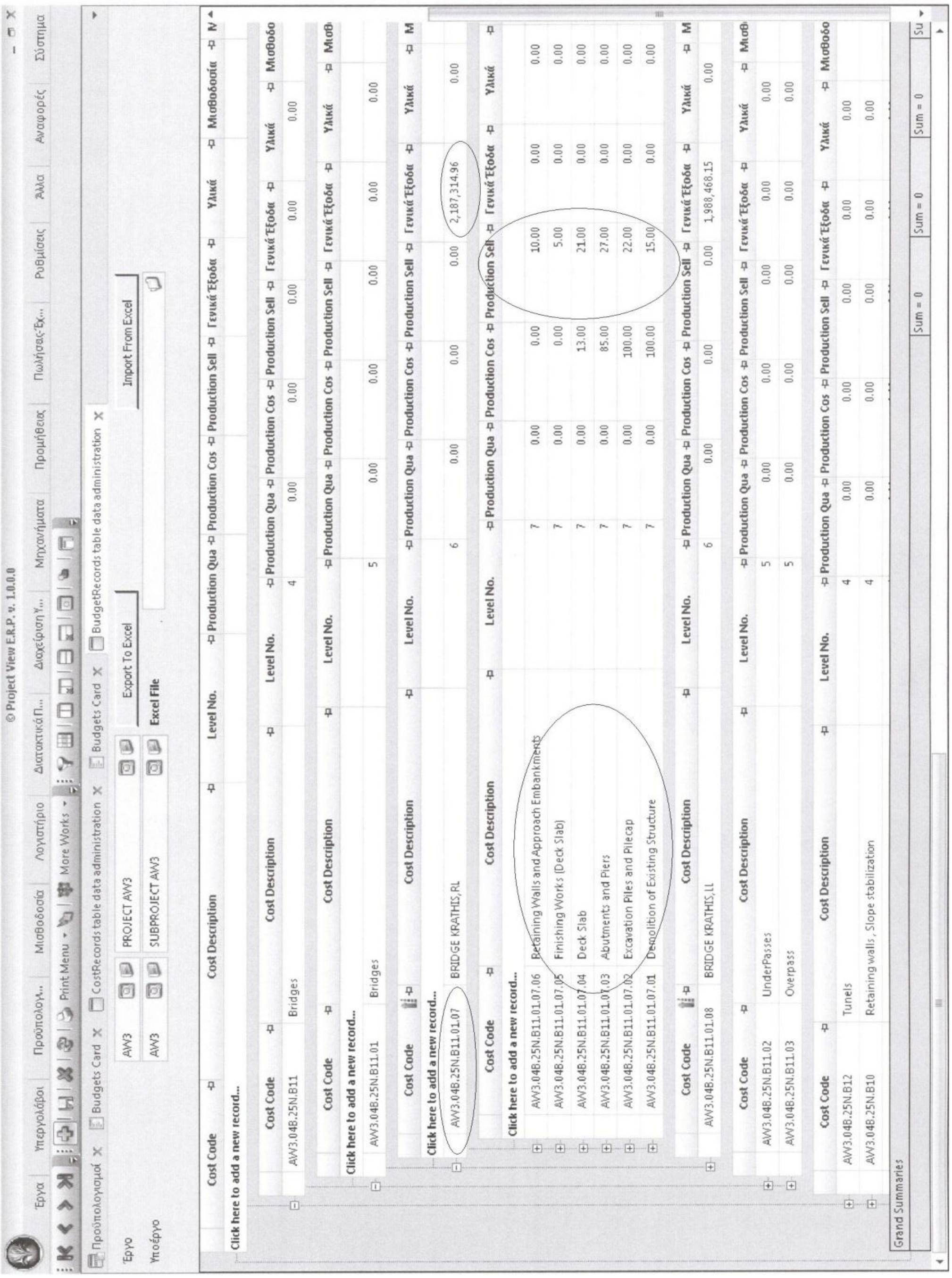
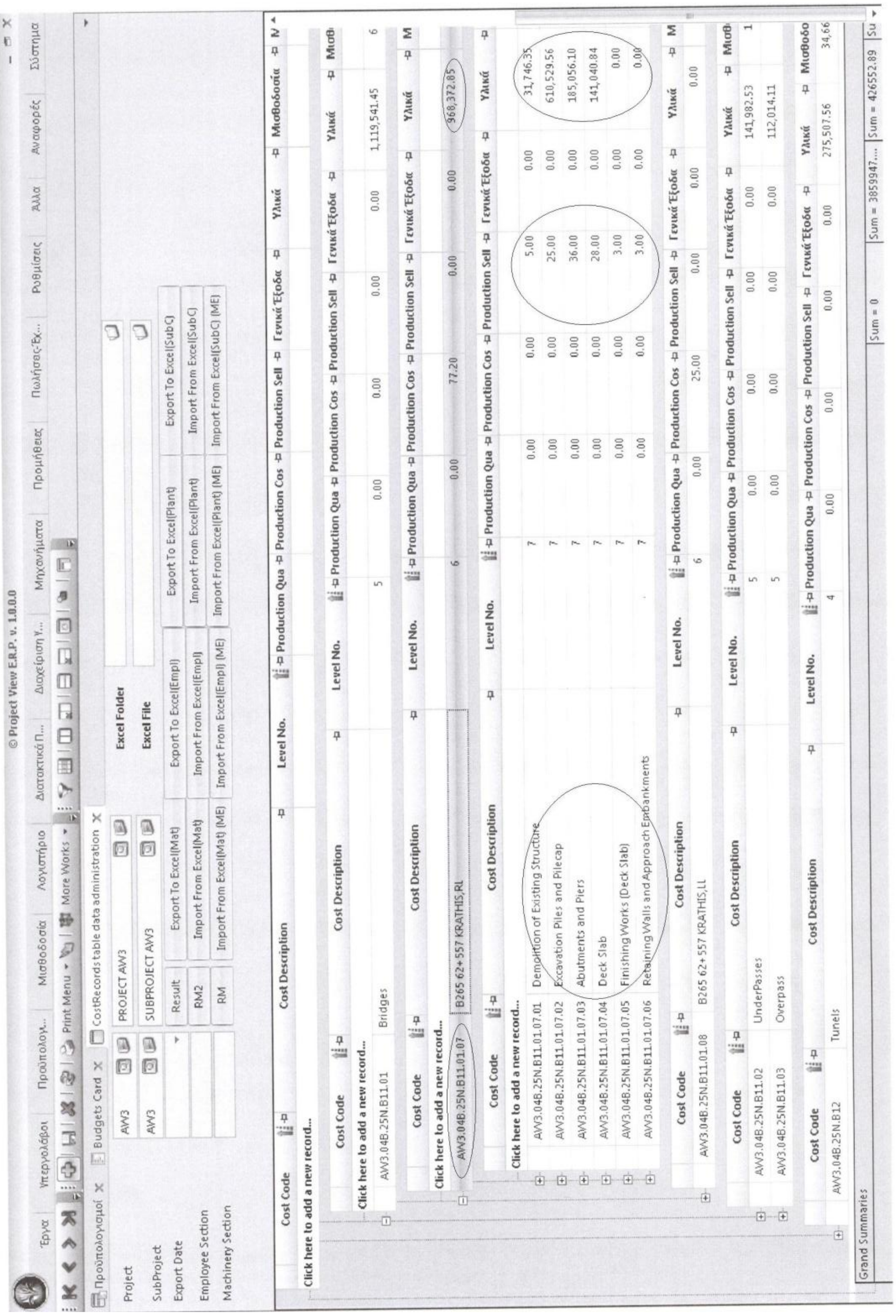


TABLE 6.3: River Bridge Budgeting environment (Source: Author's proposal)

In TABLE 6.3 an extraction of the budgeting structure of the bridge as part of the whole budgeting of the project is presented. The ID coding system for each specific stage of the WBS of the bridge can be clearly seen. The cost description cells include the description of the stages as described before, and the total budget has been calculated based on the quantities extracted from the final designs and based on the various methodologies chosen, like parametric or analogous budgeting. The final budget of this branch of the bridge is 2.187.314.96 million euros. This is the budgeting environment where information has been included and provided in weight factors in all stages. All information is exported and imported to excel in this format.

TABLE 6.4: River Bridge Actual Cost environment (Source: Author's proposal)



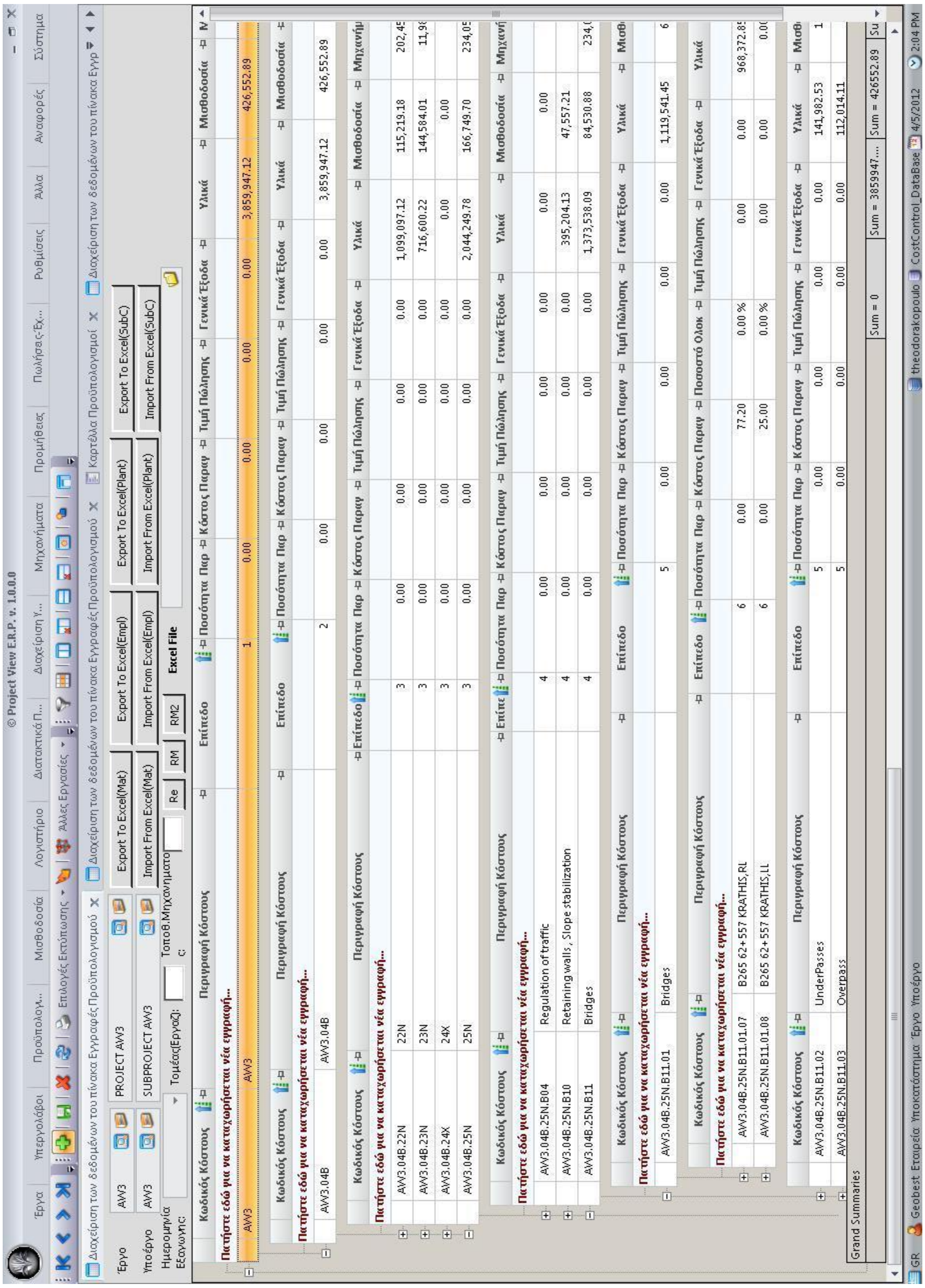
As an integrated system, which transfers information from planning stage to control stage, the actual cost has the same structure with budgeting and the same coding system. Therefore, all the construction stages of the River Bridge in the actual and the control stage include all cost information taken from the construction site. All cost information is placed in the specific code, and hence its construction stage has its own actual cost value as shown in Table 6.4. This value is the summation of its basic cost categories like: materials, labor, subcontractors, staff, overhead costs. Any information related to this cost category has been extracted to excel files to be filled in within construction sites and imported back to the integrated system.

This is a continuous process, working on a daily and weekly basis, and this environment is updated accordingly in real time.

Table 6.5 provides a more global approach of the levels of hierarchy of the project, and the bridge example in relation to the whole WBS structure which has been created.

Appendices 11, 12, 13 and 14 provide the actual information related to personnel, materials, subcontractors and plants as an import of information calendars, described for Appendices 5, 8, 9 and 10 in excel time sheets.

TABLE 6.5: River Bridge Actual Cost environment- hierarchical level structure of the project (Source: Author's proposal)



6.3.4 Parameterization and Application process

As described in Table 5.12, there are various characteristics within the ICMS-P that are personalized to the structure itself, and its unique characteristics. This parameterization process is important for the integrated system since it identifies and transfers valuable information based on real factors related to the structure. In the bridge's example, the work related to PUO reallocation, which it is important to solve prior to the construction and demolition, have been parameterized. Expropriation procedures with the state should be accomplished very early, and this information has been recorded both in the ICMS-P and also in primavera software as part of time schedule. Quantity surveying, together with the Activity cost plan, have already been described and analyzed in previous sections of the chapter, as part of the development process. In the bridge case study, it was necessary to develop an Earth Mass Haul Diagram, which describes the loads needed to be transported and the route that should be followed to deposit the earthworks. This information is being used in the relevant earthwork activity, which also affects the bridge construction. For the bridge case study, specific reports have been decided and forecast information provided since cost and time are crucial for the current structure. These reports are described in a later section of the chapter. The specialized team responsible for special parameterization is the project control manager, the project manager and the mechanical engineer.

Finally, all parameters of the bridge have been described and analyzed, such as the hydraulic design details, approvals from public services, especially for demolition, expropriation issues, and many others as shown in Table 6.2.

6.3.5 Results and outcomes

In this section of the chapter the case study of the bridge and how this integrated system supports the process from initial stage up to completion stage is analyzed. The main report below that created in Figure 6.6 is the guide to proceed with further actions and provides valuable information for the managers.

Based on the budgeting analysis and the structure, all the weight factors of the river bridge have been calculated. Each specific stage has a specific weight factor based on cost and effort variables. The integrated system has a big advantage, being able to evaluate at any time, contain all variables of the structure or the project and provide the main report for information and action.

MAIN REPORT

Print Date: 7/20/2012
Last Import Date:

PROJECT:	AW3	AW3	Real Direct Cost: 2,187,314.96
SUBPROJECT:	AW3.04B	AW3.04B	
G.U.:	AW3.04B.25N	25N	Total Value: 2,621,685.51
CATEGORY :	AW3.04B.25N.B11	Bridges	
SUBCATEGORY:	AW3.04B.25N.B11.01	Bridges	
STRACTURE:	AW3.04B.25N.B11.01	Bridges	

BCWS (budget cost of work scheduled)		77.20 %	1,688,607.15
BCWP (budget cost of work performed		66.68 %	1,458,501.62
ACWP (actual cost of work performed)		66.68 %	2,130,340.72
SCHEDULE VARIANCE	SV		-230,105.53
SCHEDULE VAR %	SV%		-13.63%
SCHEDULE PERFORMANCE INDEX	SPI		0.86
COST VARIANCE CV	CV		-671,839.11
COST VAR %	CV%		-46.06%
COST PERFORMANCE INDEX	CPI		0.68
BAC (BUDGET AT COMPLETION)		100 %	2,187,314.96
EAC (ESTIMATION IN COMPLETION)			3,194,872.11
VAC(VARIANCE AT COMPLETION)			-1,007,557.15
Cost Schedule Index-CSI			0.59
TO COMPLETE COST PERFORMANCE INDEX			12.79

BCWS : BUDGET COST OF WORK SHCEDULED
BCWP : BUDGET COST OF WORK PERFORMED
ACWP : BUDGET COST OF WORK PERFORMED
SV : SCHEDULE VARIANCE
SV% : SCHEDULE VARIANCE
SP : SCHEDULE PERFORMANCE INDEX
CV : COST VARIANCE
CV% : COST VARIANCE %
CPI : COST PERFORMANCE INDEX
BAC : BUDGET AT COMPLETION
VAC : VARIANCE AT COMPLETION
EAC : ESTIMATION AT COMPLETION
CSI : COST SCHEDULE INDEX
TCSPI :TO COMPLETE SCHEDULE PERFORMANCE INDEX
TCCPI : TO COMPLETE COST PERFORMANCE INDEX

Figure 6.6: River Bridge Main report (Source: Author's proposal)

The current control date that is analyzed in this chapter is based on the current progress of the River Bridge which is before the completion of abutments. Two middle abutments are not constructed. Hence, the remaining works are the construction of the last two middle abutments, the piers and the complete deck slab.

The date that is shown on the top of the main report is the date of the last cost entry. At the top also is shown not just the ID codes of the structure, but also the category of the structure within the project itself, so that any participant of the project knows where this specific structure belongs in the project scheme.

The main reports include two main values that are useful in any comparison: the total Real Direct Cost of 2.184.394.86 Euros; and the total value to be paid for that structure based on contract, 2.621.685.51 Euros.

The current progress percentage is 66.8% as described before.

By that time, the budget cost should have a value of 1.458.501.62 Euros, and the official time schedule indicates that the progress at the time the control was investigated should be 77.20%. That means by that time all abutments and piers should have been constructed and one set of five beams should be concreted and placed.

Instead, it can be seen that the structure is over budget and behind schedule.

There is a schedule variance of 13.63% and a cost variance of 46.06%. These values indicate that the Bridge is not progressing as planned. This is proved through the Schedule Index Performance and Cost Index Performance which are below the unit 1, which means they need to recover especially the cost index factor.

To understand how important those factors are, calculations have been made based on the budget cost and estimated final cost.

Calculations show that the Estimated Actual Cost at Completion will exceed 3.194.872.11 Euros. That means a total cost variance of 1.007.557.15 Euros. This value is almost the half the budgeting cost of the bridge.

If progress continues without acting, this variance will become reality and the Cost Schedule Index indicates that is likely to return this project on track at 0.59 performance index.

If there is any chance to put the construction back on track, then an extra effort of 12.79 is needed.

MAIN REPORT - ACTUAL VS BUDGET

Print Date: 7/20/2012
Last Import Date:

PROJECT:	AW3	AW3	Real Direct Cost:
SUBPROJECT:	AW3.04B	AW3.04B	2,187,314.96
G,U:	AW3.04B.25N	25N	
CATEGORY :	AW3.04B.25N.B11	Bridges	Total Value:
SUBCATEGORY:	AW3.04B.25N.B11.01	Bridges	2,621,685.51
STRACTURE:	AW3.04B.25N.B11.01	Bridges	

ΠΟΣΟ ΕΙΣΠΡΑΞΗΣ	%	1,643,272.48
BCWP (budget cost of work performed	66.68 %	1,458,501.62
ACWP (actual cost of work performed)	66.68 %	2,130,340.72

Figure 6.7: River Bridge Main report Actual vs Budget (Source: Author's proposal)

Before analyzing how the Integrated Cost Management System supports the decision-making policy through these reports, it is worth mentioning another main report which gives the full comparison of budget vs actual cost: Figure 6.7. This is a short but useful report, without factors and indices, and every manager needs to have that information in real time.

7/20/2012

Actual Cost Analysis

Budget Amount: AW3.04B.25N.B11.01. B265 62+557 KRATHIS,RL
2,187,314.96 Complete %: 97.40

Cost Categories	Weight Factor	Total Cost
01 GENERAL EXPENSES/RUNNING COST	8.91 %	189,829.83
02 MATERIAL	45.46 %	968,372.85
03 PERSONNEL	5.11 %	108,776.65
04 PLANT	14.48 %	308,445.12
05 SUBCONTRACTORS	26.05 %	554,916.27
Grand Totals:		2,130,340.72

Figure 6.8: River Bridge Actual Cost Analysis (Source: Author's proposal)

Proceeding to any corrective action, there must be always be a clearer analysis of the derived values. What categories are included in actual cost and what is the distribution so the manager can verify or analyze which cost category suffers, as shown in Figure 6.8? Materials underestimation, materials price changes, personnel extra working hours, plant overuse, Subcontractor's extra payments? Any reason is possible, and specifically in this construction, all cost categories are showing a loss compared to the budget analysis. In the appendices, there is a detailed analysis of those categories one by one, indicating the exact cost for specific items.

The integrated cost management system has been developed and set up for exactly this reason. To provide alternatives and solutions after it shows the results to the managers. It is the tool for any decision making not only because it provides cost details and comparisons in real time, but because it includes all those parameters designed and developed in the design and planning process that if any change occurs or any mistake happens in the process, or any unforeseen condition appears, it gives suggestions to the managers on how to decide on the future of that structure immediately (Byung, 2006).

In the bridge case study, it has been decided to minimize subcontractors extra working hours as nonproductive. This would lead to a 20% saving for the rest of the progress of the bridge. Most of plants used were in the contractor's asset system. Since the equipment was not new in most cases, there was an enormous excessive cost not only in plant maintenance, but also this had effect in materials cost and personnel cost for man hours to fix the plant. All materials were fixed in terms of unit price, and the general expenses were reduced to a minimum, with better collaboration established between site engineers and project engineers.

By using the Performance measurement analysis as a tool in the control stage, we come up with recommended corrective actions.

Control users have the responsibility to asses those reports and the reporting system and provide any relevant information to the managers based on them. The system provides many reports, as described in Chapter 5.

This suggested methodology is mainly provided by the Integrated Cost Management System, and the way this has been developed to provide any information and then project it into cost and value. The feedback process that the integrated system involves allows the manager to go back in time and check what the assumptions at that period of budgeting were and compare it with the new changed ones.

Resuming this example of the bridge, All the necessary information for the structure, verification of the process and how it works up to the final stage and validation of the results with specific reports and data information in synoptic and analytical levels have all been successfully provided.

It has also clarified action for the user groups in any stage of development and day-to- day usage, which is also very useful guidance for future contractors on how to manage staff in such circumstances. The ICMS-P provides new systems on site and processes, which allow staff to save time on calendars and time sheets.

The above case study indicates how problems can emerge during the process, and at the same time, the necessity to have such a tool to support you in any corrective action, because it contains all the information from the inception stage to the completion stage integrated in one system.

6.4 REPORTED STRUCTURE TWO: MOTORWAY UNDERPASS

The second case study refers to an underpass of a motorway, with the following characteristics.

The structure is a top down structure on piles as shown in the following figures. It is a 30m long underpass with 11.5m width and 5.5 meters height, passing under the motorway to connect old national roads and local roads.

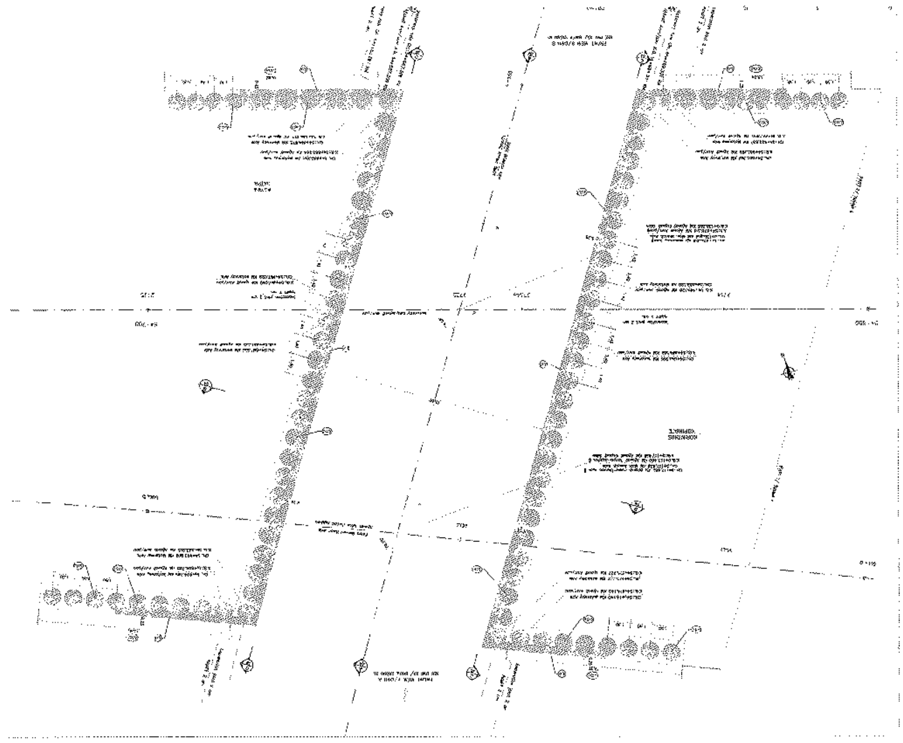


Figure 6.9: Pile view: Underpass case study (Source: Author's proposal)

As is shown in Figure 6.9, the underpass contains 68 piles on the main body walls and 38 piles on the retaining walls of the structure. The methodology is the construction of the half on the left side of the underpass by keeping the existing traffic on the right side of the existing motorway. Initially piles are constructed both in the structure and walls of the left side. Then the left side is excavated to elevation level, piles are exposed and the left side is finalized with the top slab construction.

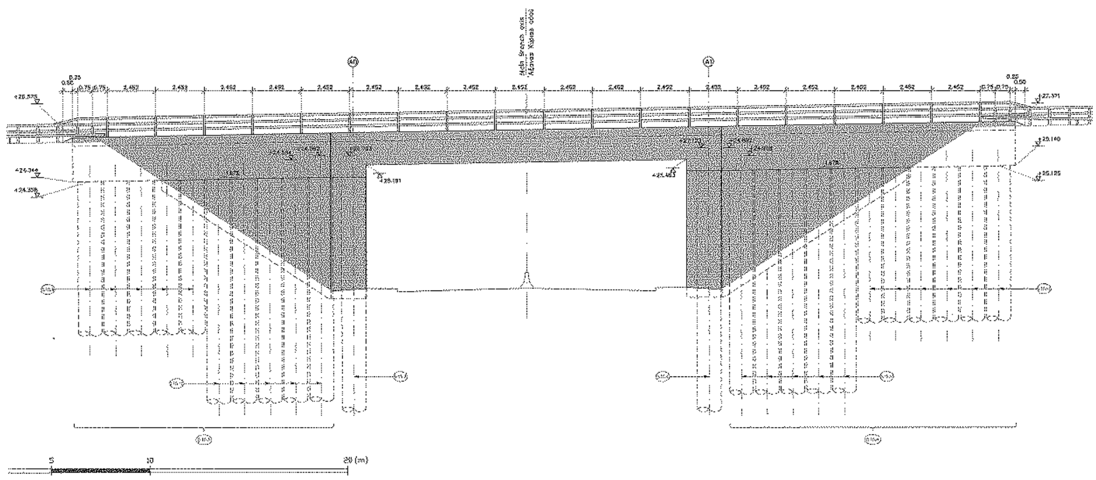


Figure 6.10: Plan view: Underpass case study (Source: Author's proposal)

The top slab, as it is shown in this plan view Figure 6.10, is being constructed in the same phase as the pile cap of the retaining structures. The tarmac is being replaced over the top slab to absorb the traffic load before the arrangement to transfer the traffic to the new left side underpass is executed.

The process is repeated with the top slab construction on the right side of the underpass.

Hence, the traffic over the underpass is being fully facilitated and now only remains construction of the final lining of the walls inside the underpass. This process is easier if it is known that the lining walls are concreted without having traffic close to the process.

The sequence of this typical underpass construction has been repeated for many others since there are hundreds of underpasses in this project scheme. Therefore, it could be argued that the unit underpass construction is being manufactured according to standard construction methodology.

The structure stages have been analyzed in the following Table 6.5

Table 6.5: WBS structure of Underpass (Source: Author's proposal)

KXXX	XX+XXX	xxx%	Weight Factors
	1. Excavation and Piles		40%
	2. Bottom Slab, Side Walls and Top Slab		40%
	3. Retaining Structures (Entrance - Exit)		10%
	4. Approach Slabs and Backfilling		10%

Table 6.6: WBS structure of Underpass with ID coding system (Source: Author's proposal)

	XX+XXX	KXXX	B11.2.02	AW3.04B.22N.B11.2.02
	1. Excavation and Piles		B11.2.02.01	AW3.04B.22N.B11.2.02.01
	2. Bottom Slab, Side Walls and Top Slab		B11.2.02.02	AW3.04B.22N.B11.2.02.02
	3. Retaining Structures (Entrance - Exit)		B11.2.02.03	AW3.04B.22N.B11.2.02.03
	4. Approach Slabs and Backfilling		B11.2.02.04	AW3.04B.22N.B11.2.02.04

As it shown in Tables 6.5 and 6.6, the underpass has been analyzed and categorized in stages. Each stage has the unique ID code based on the philosophy of the total category of underpasses.

The coding system supports the integrated process throughout the procedure, from budgeting to control and construction stage. Appendices 18, 19 and 20 show the IS environment files related to materials, personnel and subcontractors. Below, the case study of the underpass is analyzed.

The main report below Figure 6.11, as with the River Bridge case study, is the guide to proceeding with further actions and provides valuable information for the managers.

Each specific stage has a specific weight factor based on cost and effort variables. All variables of the underpass have been imported and calculated, and the integrated system has made this calculation in terms of cost and effort and time, providing valuable information to managers.

ΕΡΓΟ:	AW3	AW3	Real Direct Cost:
ΥΡΟΕΡΓΟ:	AW3.04B	AW3.04B	363,898.11
ΓΕΩΓΡΑΦΙΚΗ ΕΝΟΤΗΤΑ:	AW3.04B.22N	22N	
ΚΑΤΗΓΟΡΙΑ :	AW3.04B.22N.B11	Bridges	Total Value:
ΥΠΟΚΑΤΗΓΟΡΙΑ:	AW3.04B.22N.B11.02	Underpasses	436,964.00
ΤΕΧΝΙΚΟ ΕΡΓΟ:	AW3.04B.22N.B11.02.0:	K243 54+678	

BCWS (budget cost of work scheduled)		95.00 %	345,703.20
BCWP (budget cost of work performed		52.75 %	191,956.25
ACWP (actual cost of work performed)		52.75 %	256,257.41
SCHEDULE VARIANCE	SV		-153,746.95
SCHEDULE VAR %	SV%		-44.47%
SCHEDULE PERFORMANCE INDEX	SPI		0.56
COST VARIANCE CV	CV		-64,301.15
COST VAR %	CV%		-33.50%
COST PERFORMANCE INDEX	CPI		0.75
BAC (BUDGET AT COMPLETION)		100 %	363,898.11
EAC (ESTIMATION IN COMPLETION)			485,796.03
VAC(VARIANCE AT COMPLETION)			-121,897.92
Cost Schedule Index-CSI			0.42
TO COMPLETE COST PERFORMANCE INDEX			1.60

BCWS : ΑΞΙΑ ΕΡΓΑΣΙΑΣ ΠΟΥ ΕΧΕΙ ΠΡΟΓΡΑΜΜΑΤΙΣΤΕΙ ΝΑ ΕΚΤΕΛΕΣΤΕΙ

BCWP : ΠΡΟΓΡΑΜΜΑΤΙΣΜΕΝΗ ΑΞΙΑ ΕΡΓΑΣΙΑΣ ΠΟΥ ΕΚΤΕΛΕΣΤΗΚΕ

ACWP : ΠΡΑΓΜΑΤΙΚΗ ΑΞΙΑ ΕΡΓΑΣΙΑΣ ΠΟΥ ΕΚΤΕΛΕΣΤΗΚΕ

SV : ΑΞΙΑ ΧΡΟΝΙΚΗΣ ΔΙΑΦΟΡΟΠΟΙΗΣΗΣ

SV% : ΠΟΣΟΣΤΙΑΙΑ ΧΡΟΝΙΚΗ ΔΙΑΦΟΡΟΠΟΙΗΣΗ

SP : ΣΥΝΤΕΛΕΣΤΗΣ ΧΡΟΝΙΚΗΣ ΑΠΟΔΟΣΗΣ

CV : ΑΞΙΑ ΚΟΣΤΟΛΟΓΙΚΗΣ ΔΙΑΦΟΡΟΠΟΙΗΣΗΣ

CV% : ΠΟΣΟΣΤΙΑΙΑ ΚΟΣΤΟΛΟΓΙΚΗ ΔΙΑΦΟΡΟΠΟΙΗΣΗ

CPI : ΣΥΝΤΕΛΕΣΤΗΣ ΚΟΣΤΟΛΟΓΗΚΗΣ ΑΠΟΔΟΣΗΣ

BAC : ΠΡΟΥΠΟΛΟΓΙΣΜΟΣ ΕΡΓΑΣΙΑΣ

VAC : ΔΙΑΦΟΡΟΠΟΙΗΣΗ ΠΡΟΥΠΟΛΟΓΙΣΜΟΥ ΜΕ ΤΟ ΠΕΡΑΣ ΤΗΣ ΕΡΓΑΣΙΑΣ

EAC : ΕΚΤΙΜΗΣΗ ΤΕΛΙΚΟΥ ΚΟΣΤΟΥΣ

CSI : ΠΙΘΑΝΟΤΗΤΑ ΝΑ ΕΠΑΝΕΛΘΕΙ ΤΟ ΕΡΓΟ ΣΤΑ ΕΠΙΠΕΔΑ ΤΟΥ ΠΡΟΓΡΑΜΜΑΤΙΣΜΟΥ

TCSPI : ΑΠΑΙΤΟΥΜΕΝΗ ΑΠΟΔΟΣΗ ΜΕΧΡΙ ΤΟ ΠΕΡΑΣ ΤΟΥ ΕΡΓΟΥ ΓΙΑ ΝΑ ΟΛΟΚΛΗΡΩΘΕΙ ΕΝΤΟΣ ΧΡΟΝΟΔΙΑΓΡΑΜΜΑΤΟΣ

TCCPI : ΑΠΑΙΤΟΥΜΕΝΗ ΑΠΟΔΟΣΗ ΚΟΣΤΟΥΣ ΓΙΑ ΝΑ ΟΛΟΚΛΗΡΩΘΕΙ ΕΝΤΟΣ ΠΡΟΥΠΟΛΟΓΙΣΜΟΥ ΣΥΜΦΩΝΑ ΜΕ ΤΗΝ ΤΡΧΟΥΣΑ ΑΠΟΔΟΣΗ

Figure 6.11: Underpass Main report (Source: Author's proposal)

The current control date that is analyzed in this chapter is based on the current progress of the underpass, which is following the completion of the left side of the underpass. Piles, pile caps, retaining walls and top slab are already constructed.

At the top the ID codes of the structure are shown, as is the category of the structure up to the project itself, so that any participant of the project knows where this specific structure belongs in the project scheme.

The main report, Figure 6.11, includes two main values that are useful in any comparison. The total Real Direct Cost of €363,898.11 and the total value to be paid for that structure based on contract, €436,964.01.

The current progress percentage is 52.75% as described before.

By that stage of progress, the budget cost should have a value of €191,956.25 and the official time schedule indicates that the progress should be at 95%. That means by the time the left side of the underpass is completed, the whole underpass should have already been constructed. This situation was mainly a result of delays on traffic arrangements approvals, which was imported into the system when it occurred. Since the underpass is part of a wider part of the motorway with other underpasses, time was not an issue at that stage.

However, it has also been found that the structure is over budget.

There is a schedule variance of 44.47% and a cost variance of 33.50%. These values indicate that the underpass is not progressing as planned. This is proved through the Schedule Index Performance and Cost Index Performance which are below the unit 1, which means they need to recover, especially the cost index factor.

To understand how important those factors are, calculations have been made based on the Budget cost and estimated final cost.

Calculations show that the Estimated Actual Cost at Completion will exceed €485,796.03. That means a total cost variance of €121,897.92. This value is almost the 40% the budgeting cost of the Underpass.

As progress increases, without taking action, this variance will become reality and the Cost Schedule Index indicates that is likely to return this project on track to 0.42 performance index.

If there is any chance to put the construction back on track, then an extra effort of 1.6 is needed.

ΕΡΓΟ: ΥΡΟΕΡΓΟ: ΓΕΩΓΡΑΦΙΚΗ ΕΝΟΤΗΤΑ: ΚΑΤΗΓΟΡΙΑ : ΥΠΟΚΑΤΗΓΟΡΙΑ: ΤΕΧΝΙΚΟ ΕΡΓΟ:	AW3 AW3.04B AW3.04B.22N AW3.04B.22N.B11 AW3.04B.22N.B11.02 AW3.04B.22N.B11.02.02	AW3 AW3.04B 22N Bridges Underpasses K243 54+678	Real Direct Cost: 363,898.11 Total Value: 436,964.00
ΠΟΣΟ ΕΙΣΠΡΑΞΗΣ	%	220,666.82	
BCWP (budget cost of work performed	52.75 %	191,956.25	
ACWP (actual cost of work performed)	52.75 %	256,257.41	

Figure 6.12: Underpass Main report: Actual vs Budget (Source: Author's proposal)

Before analyzing how the integrated cost management system supports the decision-making policy through these reports, it is worth mentioning another main report which gives the full comparison of budget vs actual cost as shown in Figure 6.12.

Αναλυση Πραγματικού Κοστους 8/8/2011

	AW3.04B.22N.B11.02.02	K243 54+678	
Budget Amount:	363,898.11	Complete %:	70.42

Κ.Κοστους		Ποσοστό Συμμετοχής	Συνολική Αξία
02	MATERIAL	53.32 %	136,645.57
03	PERSONNEL	6.87 %	17,610.56
05	SUBCONTRACTORS	39.80 %	102,001.28
		Γενικά Σύνολα:	256,257.41

Figure 6.13: Underpass Main report: Actual vs Budget (Source: Author's proposal)

As explained in the previous example with the River Bridge, before proceeding to any action there must be always a clear analysis of the cost basic categories cost (Figure 6.13). Questions about what categories are included in the actual cost and what the distribution is need to be answered so the manager can verify or analyze which cost category suffers. In the appendices, there is a detailed analysis of those categories one by one indicating the exact cost for specific items.

The integrated cost management system has been developed and set up for exactly this reason, to provide suggestions to the managers.

In the underpass case, it has been found that there was an excessive cost in materials. An incorrect estimation of reinforcement and concrete costs created an increase of 53.32% in the cost of materials. It has been decided to accept the cost for half of the underpass, but the initial budgeting has been revised for the second, right side of the underpass. The risk has been undertaken fully by the contractor, but the comparison was no longer based on underestimated cost but in real terms. It has been successful, then, in controlling equally the underpass with the correct baseline budget, and not the wrong one. By using the performance measurement analysis as a tool in the control stage, we have come up with a recommended corrective action.

The above case study indicates how problems can emerge during a project, and at the same time, the necessity of having such a tool to support you in any correction activities because it contains all the information, even that the initial budget was not estimated correctly. The feedback process allows managers to have a clear picture of the comparison and real cost of the structure.

6.5 ICMS-P AS A DECISION-MAKING TOOL

The data used by the integrated system are related to the project variables and factors. Each piece of data follows the internal mechanism flow process and can be either in the planning stage or in the control stage (Figure 6.14).

The linkages of each stage are also the connections within the system, where specific data are transformed into an output

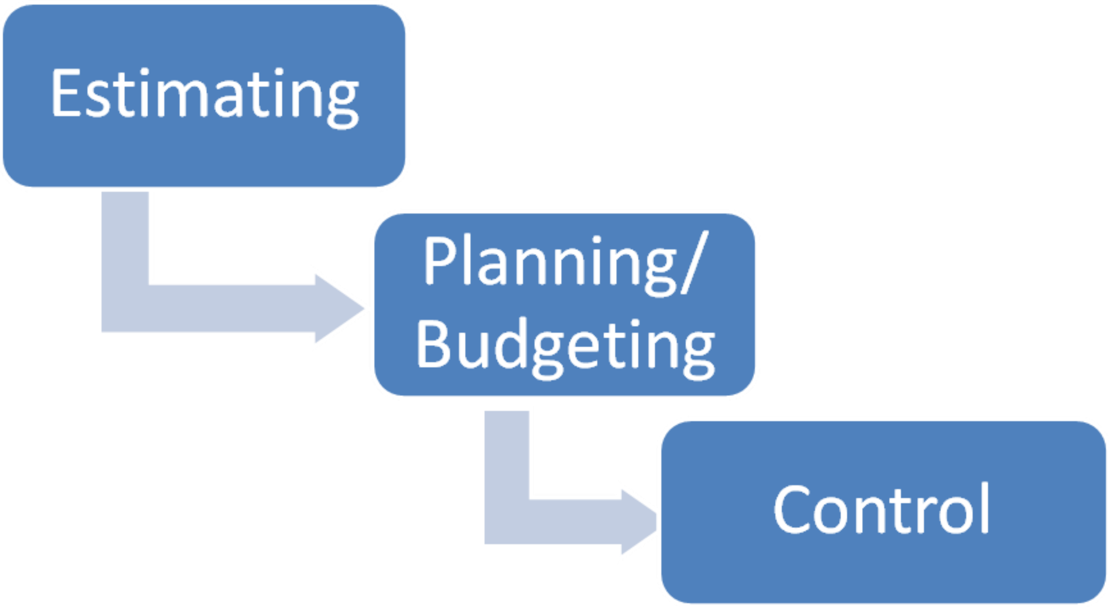


Figure 6.14: Integrated System linkages (Source: Author's proposal)

In the following discussion, a clear example of how the Integrated Cost Management System becomes a powerful tool for decision making policy is described.

Approved change requests in a design (field of change) is an output in a budgeting process and can be used as an input in the control stage.

By using Performance measurement analysis as a tool in the control stage, we come up with a Recommended corrective actions data.

Figure 6.15: Lane Cover Construction Case (Source: Author's proposal)

In photo, Figure 6.15, you can see a lane cover 252 m long, with 1500 mm pile diameter both in the north and south side.

Current progress is piles of north side. The Initial design issue for construction and method of statement defines a specific sequence of construction with construction of piles North side, then the earthworks (fills and cuts) are made, and then construction of pile wall in south side is completed. Finally, the lining walls and the top slab are constructed.

The integration system I propose, based on the design parameters and the construction phases, provided all the necessary information of budget, time, effort, resources and traffic arrangement issues.

At some time, during the second stage, part of the slope collapsed despite using gunite together with nails as laid out in the design.

Finally, part of the slope with the gunite collapsed and stopped at the North pile wall, meters away from the traffic. The procedures demanded preparation of a field of change for the design. to proceed to reconstruction.

Since the situation was critical in terms of time and cost, the best economical solution should be found and, at the same time, be acceptable and quick.

At this point, through using the system, we are able to evaluate all the possible solutions like constructing a double pile wall, or excavating a new big cut inside the mountain to reduce the acceleration of the soil.

The integration cost management system provided a simulation of all possible solutions to the project manager, and after the risks of each solution had been explained, the most efficient was chosen in terms of budget and time.

It was found that building a pile wall just above the body pile wall of the lane cover to keep the mountain stable was the optimum solution. The solution of creating a new cut to the mountain would have led to more than 40,000 m3 of earthworks removal, which is uneconomical and time- consuming compared with building an extra pile wall.

This is one of many examples where the system is used to decide how to change our program of work, and how this can affect our initial plan. Today, all changes have been evaluated and a decision made to include them or not in relation to the initial design process. As can be seen, any action is known and simulated before taking place, and the project manager knows what will be the result before the change is constructed.

The whole budget has been revised, the time has been revised and every new parameter of the field of change has been integrated and compared with the baseline approach.

The variances have been kept in a separate database and any comparison from now on with the initial design will be made based on three main characteristics:

1) Keep the risk, therefore we do have comparison with the baseline
2) Transfer the risk and claim the amount
3) Minimize the risk and compare the initial quantities (keep the excess budget out of the system

6.6 ICMS-P Benefits and Outcomes

It is worth mentioning the main list of benefits and outcomes which are derived from such a system. Integration is the main benefit which reduces the cost of uncertainties in construction projects. This is solved by the elimination of poor communication of information linkages generated in traditional cost management approaches. This, in turn, leads to making cost the driver for design, thereby reducing waste and increasing the value of the project.

The Integration system, which has been found to be very useful, was based on a very simple hypothesis based on the basic initial problems of projects: how the project is going to be delivered, with what cost and what resources. Beyond that, cost control and cost management, from inception to completion, in a dynamic process is a dilemma that is being answered with the proposed integration system.

The simple interim mechanism of integrated stages of estimating, budgeting, and control makes the system novel since there are no boundaries in the process, and minimum errors. The feedback process simplifies omissions and secures the process efficiency.

6.7 SUMMARY

All the case studies examined in this research indicate the necessity of using the proposed Integrated Cost Management System in conjunction with the valuable information generated in projects which can lead to a change in decisions and change in methodology resulting in using resources in a more efficient way. The numbers on figures have been revised for the research purposes keeping the values in real terms for better understanding for the researchers and the contractors and clients.

In the future, this system will be analyzed in more structures, and in a complete project scheme as it was designed for. In a whole project scheme, all the factors of the project, together with the starting agreement or starting contract, will have been imported and categorized to various structures and various working packages.

ICMS-P can be applied in projects worldwide since the regulations of the current application are global and related to EU regulations and legislations.

CHAPTER SEVEN: DISCUSSION

7.1 Significance and Benefits of the ICMS-P

Among the benefits that derive from the development of the ICMS-P solution are the following salient points.

1. ICMS-P is a complete integrated system that uses cost management as a core function of delivering the projects because cost management can lead the project management procedures as described and proved from the application of the ICMS-P.

2. The integrated system does not use cost management as a functional solution but brings the participants together to work toward solutions, as supported by user participation in all stages of the procedure.

3. The construction industry can rely on the integrated cost management system (ICMS-P) as a complete process in delivering projects and an alternative to current approaches. It is built on the basic principles of managing projects and provides results and suggestions for decision making policy as described in Chapter 6. It is innovatory in all the stages of cost and project management, allowing companies and managers to use it as a powerful decision-making tool.

4. ICMS-P is a core part of the total project management, and each organization is able to apply this integrated system to its functional operation. The architecture of the ICMS-P can be used with any project operation of a company's projects.

5. The ICMS-P is the integrated cost management system that the market needs and that enables everyone to look in the same direction to achieve project success. Integration is no longer a software or a mathematical approach. It has become a process of delivering construction projects.

7.2 Usefulness of the ICMS tool for project decision support

The ICMS-P is a unique system, its development based on the needs of project managers and companies. Its significance is found in supporting decision making policy for each of the participants in the project. This decision-making policy flows through all project stages, providing the logical sequence to deliver the project. In each stage, all information used is transferred for future use in the following stages and, at the same time, provides the most efficient suggestions for the following stages which will lead to project delivery. It is a dynamic process that remains stable in all stages of the project without fading through lack of information or lack of data, unlike other systems.

7.3 Response of the ICMS-P to current market and industry demands

It brings cost management into the core of the project and leads the procedures and the processes of the project. The ICMS-P is a system that connects all parties and all participants to move towards a solution. It provides a communication, cooperative and problem- solving attitude. The Integrated Cost Management System provides a proactive means for project control and can be a cost driver for design, construction and operation; hence, reducing waste in the project, and increasing the value to the clients. All stages of integration now share the same aim of delivering the project and maximizing its performance. The market needs a system that can be applied at any stage of a project, even if the information or the data are adequate or limited. The construction industry needs a system that can control and support project managers until they deliver the project. The ICMS-P is the integrated cost management system that enables everyone to move in the same direction towards effective project delivery. Integration is no longer software or a mathematical approach. It has become a process of delivering construction projects.

7.4 Further potential of the ICMS-P

ICMS-P is the basis for expanding the integration process to all information sectors, not only in cost management. The future potential would be this system to become a dynamic process within the organizations as part of the solution to the general call for an Integrated Project Delivery (IPD) approach to enhancing delivery in construction.

Integration has become a process, a system that can be adjusted by any employee or manager who is part of the project. It increases the value of the project and the value of the company itself. The ICMS-P was born out of the necessity to forge a link between the human need to deliver a task or a project and the project itself. It is the connection between the human factor and the action required.

ICMS-P is about to be used in more complex structures in Europe, and then expanded worldwide through international regulations and organizations and through individual approaches within contractors.

7.5 Significance of the objectives achieved in this research

1. The established current knowledge base allows a clear understanding of cost management as a vital process in project delivery. Furthermore, the established current knowledge base of existing practices related to cost management is enabled to identify and investigate all the limitations and gaps that existing practices offer. Additionally, current aspects or methods in the estimation and control stage are part of a complete integration process delivery, with strengths and weaknesses. Finally, it is important that through the established knowledge base, including cost management as a core function of project management is highly important in this process, especially in such a complex environment as the construction industry.

2. The system development requirements, the system mechanisms used as inputs, outputs and channels (processes), are highly important. Investigations conducted provide results which any researcher or company could address or use to support their project delivery processes. The system components are in a common unified language that the company can adjust for their own processes. Therefore, the work conducted to develop a prototype framework of requirements which are integrated into a specific sequence of actions makes it the basis for additional research and development.

3. The ICMS-P development, including the architecture of the ICMS-P and the internal mechanism, is a unique process, and its significance is found in the results in the case studies .It is a complete integration system ready for delivering to projects in the construction industry. ICMS-P development is a valid guide for all project managers and upper management within companies, and so supports the decision making in any stage of a project. The variables of this ICMS-P are the memoranda for any project. The application of the integrated system using a PIS environment is the tool that allows users and managers enjoy the benefits of the Integration process, from design to control stage with feedback. Furthermore, the development of the application of the integrated system allows an effective simulation of the outcome as clarified in the reported case studies.

4. The recommendations of how the system can be used have been clarified in Chapters 5 and 6. Recommendations are related to the way that the system could be addressed and implemented, and a definition of the team responsible for running the ICMS-P in all the stages of the project delivery, together with a clarification of their job descriptions that the system demands. The significance of the recommendations for use is highly important because it gives the upper management a clear picture how to operate and how to establish the staff policy. With the

recommendation guide, a project manager is able to control all aspects of the staff involved in the process.

5. The testing process of ICMS-P in real structure case studies has great significance for the impact on the integration process and the project delivery. Initially, the orthodoxy of the procedure undertaken has been verified and the validity of the results and the outcomes confirmed. Furthermore, the testing is significant due to the fact that, through the case studies, all the possible solutions provided to the managers for decision making policy, after an evaluation of any variance of initial planning targets, were accepted. Finally, testing in real case studies has clarified the justification of the prototype version of the ICMS-P with a strong justification not only because of the final outcomes, but also because of the users' participation and how the ICMS-P designated the teamwork and group work. This is highly important since the structure of a working environment in a project delivery scheme is known.

6. All the objectives addressed lead to the final aim of developing and trialing a cost management system which *integrates* the planning and control stages of the delivery of projects in the construction sector. This is not only significant, but opens new approaches of how industry can move on from here. It is a guide to establishing a new ground for the construction industry in delivering projects

7.6 Novelty of ICMS-P vs Others

The innovatory nature of the ICMS-P, clarified in Chapter 5, automatically makes it a leader among existing approaches related to integration in cost management. All systems, methods, approaches and models in the market address specific parts of the project, hoping to offer the solution needed to deliver a project. In fact, they represent only part of the picture, or an individual stage of the project delivery process. The traditional Estimation Systems found in the literature are limited to the estimation stages, with less involvement in the control and construction stages. This is mainly due to the lack of integration. The literature shows that the BIM methodology is a strong method in the design process, but that it fades as the project progresses. Lack of integration is mainly the reason for the existing approaches fading in the project delivery process. Control Methods, by definition, are strong in the control stage, but little involvement is found in the estimation stages. ICMS-P is a system that keeps the involvement constant in all stages, due to the integration procedures and the design of the system itself.

An attempt to illustrate the involvement of each of the systems described would lead to the following illustration: Figure 7.1. Figure 7.1 represents a comparison of other systems with ICMS-P. The 0 to 6 is the level of contribution of each system in project delivery. The 0 to 6 level is being chosen as a scale to represent clearly the results in the graph. While the ICMS-P is highly involved in the project delivery in all stages, the other systems only partially contribute in project delivery. The gap between them in each stage is the lack of involvement in successfully delivering projects. The stability of the ICMS-P in all stages of project delivery makes it a pioneer in the process of integration. Deep involvement in all the stages of project delivery is the feature that companies should look for when they use systems to deliver their projects.

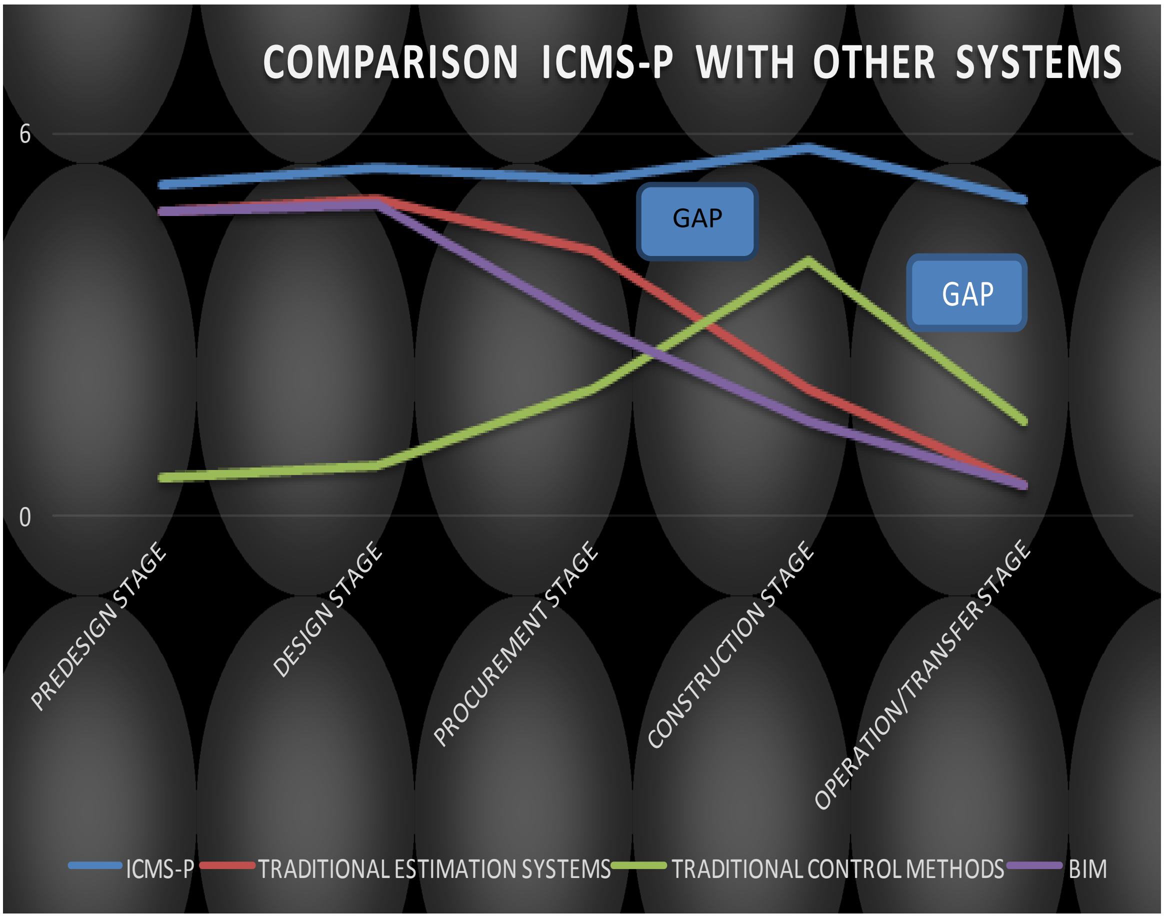


Figure 7.1: Comparison of ICMS-P with other systems and methods (Source: Author's proposal)

CHAPTER EIGHT: CONCLUSIONS AND RECOMMENDATIONS

8.1 OVERVIEW

This chapter presents the overall review of aim and objectives and explains that each of them has been addressed within the research. Furthermore, the chapter reviews the overall conclusions, future potentials and recommendations for future work. The current chapter also describes the contribution of this research to the knowledge.

8.2 RESPONSE TO OBJECTIVES

8.2.1 OBJECTIVE 1: ESTABLISHEMENT OF CURRENT KNOWLEDGE BASE FOR THE STUDY

The first objective was to explore and understand the worldwide literature concerning the field of managing costs in project delivery processes and the field of cost management processes. The review of literature within the construction industry highlighted the current practice and theory of managing contemporary projects based on traditional approaches developed in the past. Most of the findings shed light on the gaps and limitations of traditional approaches in managing costs, and at the same time the lack of any integration between the estimation/planning and control stages of projects. To meet the objective, the literature was expanded to cover many project schemes and complex projects and, at the same time, those with different contracts, as found in current practice.

Additionally, this objective was achieved by the analysis and investigation of all methods and aspects of managing costs such as a comparison of ABC methods of estimation and parametric estimations, or by presenting all the advantages and disadvantages of current practice. Furthermore, the findings from achieving the current objective highlighted the current constraints in managing project cost, and supported the need to explore and establish the requirements to develop an integration process and lead the research to the related procedures.

8.2.2 OBJECTIVE 2: SYSTEM REQUIREMENTS ANALYSIS AND DATA COLLECTION WORK

Arising from the literature was found the needs to develop an integrated process. A lot of work has been done to accomplish this objective which is one of the most vital and key objectives of the whole research. To achieve the objective and set up the framework of requirements of such an integrated system, a prototype list in stages was developed and described according to the integration processes.

Table 5.1 in Chapter 5 provides the basic requirements needed to proceed with the development of an integrated system. The requirement analysis, with the presentation of inputs, outputs and channels/techniques, constitutes the start of the system development process and the architecture of the integrated system.

The framework of requirements in all the stages of cost management and integration processes is the main finding of this objective.

8.2.3 OBJECTIVE 3: DEVELOPMENT OF A PROTOTYPICAL VERSION OF THE INTEGRATED COST MANAGEMENT SYSTEM

The integrated system development objective is the core of this research. Any methodology, any approach applied and any information used has one purpose; develop an integrated cost management system that could be applied in real project life cycles. The objective has been achieved and various stages followed to accomplish the ICMS-P.

The analysis of the framework requirements and characteristics of the system provides the basis to build the PIS Environment where the System will be developed. The PIS Environment is an important aspect and has been developed to support and connect the System development and the application of the system. The Internal Mechanism of the System that has been adopted becomes the keystone to the System Architecture and provides the time process in each stage of the system implementation. The Integrated Mechanism of the System is used to connect the planning and control stages, and becomes part of the System Architecture development.

To fully meet the current objective, a complete prototype framework of requirements to support the integrated system and any parameterization process that supports the application of the integrated system in real projects was developed.

Initially a framework of requirements of the cost management stages to support the system was developed. The following findings relate to the Internal Mechanism of the System and the Integrated Mechanism of the System, which finally led to the main finding, which is the System Architecture. The objective of Development of a prototypical version of the Integrated Cost Management System has been achieved with the System Architecture developed and the mechanisms adopted.

8.2.4 OBJECTIVE 4: CODING AND DEVELOPING THE APPLIED MODEL OF ICMS-P

The current objective has been accomplished with the analysis of the first two stages of the ICMS-P. Initially, a coding process on which the system could be applied in a PIS environment was developed. The coding process has been used as the architecture to integrate the planning and control stages. The coding format used in planning and in the control stage has been developed in a PIS environment with budgeting and actual interface, which is clarified and analyzed in stage two of the system development. The development of the applied model is strong evidence of how the system is operated and how it could be used in real projects. The IS environment used is in simple format, and a lot of research has been done to develop the application of the integrated system to be as simple as possible. The main findings from this objective are the application environment that has been developed and the way that the application must be developed to support the real conditions of the projects.

8.2.5 OBJECTIVE 5: PARAMETERISATION OF THE SYSTEM IN COMPLIANCE WITH CASE STUDIES

The successful application which is also stage three of the ICMS-P development was necessary in order to run the integrated system and make it work and also be functional for project delivery. The parameterization process focused on and succeeded in matching the system components to the project stages and packages, and presented the results to a reporting system through the initial applied model.

These factors have been developed through a close investigation of the researcher and analysis of real problems under unique conditions. The current objective has been achieved through the matching of the real conditions and the selected methods and processes of the ICMS-P. Parameterization of the system has been accomplished by using all these factors to enhance the application of the system in real projects, and succeeded having a better projection of reality, providing managers with a useful action plan to proceed in construction.

8.2.6 OBJECTIVE 6: SET OF RECOMMENDATIONS FOR THE USE OF THE NEW SYSTEM

When parameterization has taken place, it is important the contractor or the client deal with those factors.

This objective has been achieved with the completion and discussion of results found with the application of the integrated system achievement. Clarification of how users will deal with the system and a guideline of how to these people should use the system has been drawn up and analyzed as part of instructions of the ICMS-P and its sub- packages. Guidelines have been set up, which are described in Chapter 5 as “milestones”, so the managers and the users know how to achieve the sequence of work required implementing the ICMS-P. Furthermore, how the user groups and managers participate in the day to day management of the ICMS-P has been clarified and justified through the real case studies. The description of the roles provides the upper management with a picture of how to establish and implement the ICMS-P in their project delivery.

8.2.7 OBJECTIVE 7: TESTING AND VALIDATION

With the completion of the system development and the application model as it appears in this Chapter, it is confirmed that the integrated system is verified for its function usage. The results and calculations presented provide adequate verification of the system and the model, and how this is applied in real projects. The results and indices that have been produced with calculations are valid and their validity appears also in the case studies.

The Objective has been achieved with the testing of the ICMS-P in real structures from a real project implementation when the research was conducted. The specific structures chosen are part of a multi scheme motorway project. To meet the objective, the ICMS-P implementation and the values and the results of the reporting system of the ICMS-P and how these affected the decisions made for the completion of the structures had to be validated. The user participation within the alpha version of the system narrowed to a specific project and structure throughout the life cycle was also clarified.

The case studies have been analyzed and described through the explanations in the Appendices, which have been provided with real data together with the description of participants' role in all the stages of the system implementation, starting from the initial stages and concluding with the real report control status. The integration needs and specifications development provide strong evidence of the validity of testing the real case studies.

Finally testing in the real case studies has been clarified and it validates the ICMS-P with a strong justification of the final outcomes and the user participation in the ICMS-P implementation.

8.3 GENERAL CONCLUSIONS

The research reported in this Thesis examined and developed an integrated cost management system for project delivery. The aim of investigating established the essential features and the development of an integrated cost management system has been achieved through the methodology adopted to meet the research objectives.

After conducting this research, some general conclusions related to the research and the ICMS-P as a project delivery system can be extracted.

The integrated cost management system enables the identification and resolution of the problems of poor linkages that predominate in the use of the traditional cost management methods. The main conclusions are strongly connected with the objectives of the research, providing valuable information for future researchers and professionals.
The main conclusions derived from the current research and described previously in this Chapter, are not the only conclusions related to the current research. The new integrated cost management system (ICMS-P) that has been developed in this research is a valid guide for all project managers and upper management within companies, as it supports the decision making in any stage of the project.

In general terms as it is approved, this system is: a powerful tool for policy; making full Integration of information from design to control stage with feedback; effective in simulation of the outcome; providing all possible solutions for decision making; and after an evaluation of any variance of initial planning targets, enabling project manager to control all aspects and staff involved to this process.

The benefits for the construction industry are significant as discussed, and the contribution of the ICMS-P to the Project Delivery process makes it a complete process in delivering projects. ICMS-P is a decision-making tool for all project managers and upper management offering continuous support in all the stages of a project's life cycle.

8.4 CONTRIBUTION TO KNOWLEDGE

The research that is presenting in this thesis has contributed in project delivery process and has important contributions to knowledge.

The system and application present new contributions to the subject of cost management.

- A transformation of practice, of knowledge of how projects could be delivered.
- A demonstration of how integration can be achieved as a complement to the general call for an IPD approach to enhancing delivery in construction.
- A solution that ensures transparency and alignment of cost information throughout construction
  - This helps to overcome the consequences that current approaches obtain
  - It also creates a common understanding of cost related information for the various functions involved in the delivery of projects (from the design, to the completion)
- The identification of the key features for developing cost systems in construction.

Going back to the principal question of the research, the answer is yes; it is possible to develop a cost management solution that integrates the conceptual phase, the controls of the execution phase, along with the essential costing information for executive decision making to support the delivery of the project.

This is new ground for the construction industry in how projects can be delivered. It is new ground in the development of approaches towards this solid solution of the ICMS-P and towards the IPD as a whole.

8.5 POTENTIAL FUTURE DEVELOPMENTS

Current research has identified some limitations that need to be re-investigated or future research to further develop this study.

8.5.1 Limitations of system framework developed

The system framework has been designed for a project in its initial stage. All factors and parameters described are investigated in the initial stages. The reason for that approach was that a full integration process can be achieved only if the system is applied in the initial stages of the project. It does not mean that integration cannot be achieved in later stages, but the results that any manger needs can be accomplished with higher efficiency if applied early in the project life cycle.

The framework of the system is being developed for contractors' and clients' side. It is not valid for subcontractors due to the need to apply the whole contract of the project and its specifications during the integration process.

The PIS environment chosen is a simple form, designed and developed for today's needs. If an organization or a company has a more complex operation than what I have investigated in this research, then the system must be re- generated, based on an organization functional operation.

8.5.2 Resources and Time Constraints

Due to limitation of time and resources, the primary data were taken from real projects but not for all the project schemes. This limitation does not affect the process or the validation of the system and the model, but it could improve the factors' and requirements' analysis in parameterization process. The research analysis time constraints created the need to complete the analysis and processes with current data and available resources.

8.6 RECOMMENDATIONS FOR FUTURE WORK

The current research conducted, has identified several areas that requires further research in this field of cost management.

8.6.1 Recommendations for factors and requirements in integration system

There is a need to expand the integration process to all information, not only in cost management. The future aim of this research would be that this system becomes a dynamic process for organizations by enabling other core areas of project management to be adjusted and harmonized with the ICMS-P.

The research could move forward in investigating a wider spectrum of factors in each specific stage that have been described in this research. The factors that have been investigated could be expanded into different projects such as power plants, and other energy infrastructure projects or complex industrial structures. It is important to assess and evaluate as many contracts as possible and consider more factors within the integration process. This would lead to fewer problems and the maximum performance of the system.

8.6.2 Recommendations framework system development prototype

It is highly recommended to support widely used formats in the system development. Common projects can lead to common frameworks of the ICMS-P among companies; hence, more organizations or companies can adopt these frameworks, so they can use the ICMS-P in a more efficient way. If the integration process could be unified and it covered a higher percentage of companies and organizations, then it would be a great success and research would have made a great step towards the construction efficiency in terms of understanding and executing projects as planned.

The framework that has been developed in this research has feedback channels of information transfer that allow revisions in the whole process. It is highly suggested to first analyze all the requirements of the system and then proceed with the development of the system; if not, then the process would lead to an enormous number of feedbacks throughout the project’s delivery process.

8.6.3 Recommendations for general management and cost management

It would be worthwhile improving the whole process of integrated cost management systems within organizations.

From current research, it is derived that the integrated cost management system that has been developed is a complete managerial process, which aims to generate information to support decision making and to stimulate cost reduction, value improvement and continuous improvement in the organization. Based on this result it is worth trying to foresee the extensions of such a development. Each organization involved in this process could provide valuable information to a global database of factors and requirements, and make the integration process of cost management a global process, as a general call of IPD, that could provide suggestions and solutions to the managers by calculating almost all the variables of the project that a human or a team of humans cannot predict. This improvement must be supported in real terms with real information derived from real situations and projects. Current research and system development can support this option and guide it towards a more global supportive investigation with the final aim of fully integrating the planning and control processes.

REFERENCES

1. Afetornu, C., 2011. *The influence of estimator attitude on project cost reliability*. PhD Thesis, Loughborough University.
2. Akbiyikli, R., 2013. Performance assessment of a Private Finance Initiative road project. *Transport,* **28(1),** p 11.
3. Akintoye, A., & Fitzgerald, E. 2000. A survey of current cost estimating practices in the UK. *Construction Management and Economics,* **18**(2), p 161-172.
4. Amer, F., 2014. *A dynamic scheduling model for construction enterprises*. PhD Thesis, Loughborough University.
5. Antoniadis, D N, Edum-Fotwe, F T and Thorpe, A., 2006 Project reporting and complexity. In: Boyd, D (Ed) *Procs 22nd Annual ARCOM Conference*, 4-6 September 2006, Birmingham, UK, Association of Researchers in Construction Management, p 123-133.
6. APM Body of Knowledge 2006 Guide. Association for Project Management 5th edition. APM Knowledge
7. APM Body of Knowledge 2013 Guide. Association for Project Management 6th edition. APM Knowledge
8. Asmar, El M., Hanna, S. A., and Whited, C. G., 2011. New approach to developing conceptual cost estimates for highway projects. *Journal of Construction Engineering and Management.* **137**(11), p 942(8).
9. Atkinson, A., Kaplan, R. S. and Young, M., 2003. *Management Accounting*. 4th ed. Prentice Hall.
10. Baiden, B. K., 2006. *Framework for the integration of the project delivery team.* PhD Thesis, Loughborough University.
11. Baiyi, L., 2008. *Managing a collaborative preconstruction planning process.* PhD Thesis, Loughborough University.

12. Bajaj A, Gransberg D, and Grenz, M., 2002. Parametric Estimation for Design Costs. 2002 *AACE International Transactions.* ABI/INFORM Research, p 81.

13. Baldwin, A., and Bordoli, D., 2014. *Handbook for construction planning and scheduling.* Willey Blackwell.

14. Ballard, G., 2000a. *The last planner system of production control.* PhD Thesis, University of Birmingham.

15. Ballard, G., 2000b. Lean Project delivery system. *LCI White Paper.* **(8).**

16. Ballard G., 2006. Rethinking Project Definition in Terms of Target Costing, In: *Proceedings IGLC-14, July 2006. Santiago, Chile, 2006*. IGLC NET

17. Ballard, G., 2008. The Lean Project Delivery System: An Update. *Lean Construction Journal.*

18. Barnes, N. M. L., 1977. Cost modeling – an integrated approach to planning and cost control. *Engineering and Process Economics.* **2,** p 45-51.

19. Baxter, et al., 2010. *How to research.* 4th ed. Maidenhead: Open University Press.

20. Berends, T. & Dhillon, J., 2004. An analysis of contract cost phasing on engineering and construction projects. *The Engineering Economist.* **49**(4).

21. Bernand, D., 2000. The scientist's world, Limited scope of science. & Technology Microbiology and Molecular Biology Reviews. *American Society of Microbiology.* **64** (1).

22. Bernstein, H.M. et al., 2012. Contractors have become the leading users of BIM. *Building Information Modelling.* ENR. **269**(16).

23. Bicheno, J. and Holweg, M., 2009. *The Lean Toolbox (The Essential Guide to Lean Transformation, Buckingham, Production and Inventory Control, Systems and Industrial Engineering*). 4th ed. PICSIE Books.

24. Bingham, T., 2011. *BIM: Too many cooks*. Building.[viewed August 2015]. Available: http://www.building.co.uk/legal/bim-too-many-cooks/5026023.article

25. Boyce, C and Neale, P., 2006. *Conducting in-depth Interviews: A Guide for Designing and Conducting In-Depth Interviews*. Pathfinder International.

26. Brains, C., Willnat, L., Manheim, J., Rich, R., 2011. *Empirical Political Analysis*. 8th ed. MA: Longman, p 76.

27. Briciu, C. V., Filip, I. & Indries, I. I., 2016. Methods for cost estimation in software project management. *IOP Conference Series: Materials Science and Engineering.* **106**(1), p 10.

28. Bryman, A., 2014. June 1989 and beyond: Julia Brannen's contribution to mixed methods research. *International Journal of Social Research Methodology.* **17**(2), p 121-131.

29. Cagle, R. F., 1991. Implementing an Owner's Cost Control System, *AACE Transactions*, Seattle, 1991.

30. Caputo, A. C. & Pelagagge, P. M., 2008. Parametric and neural methods for cost estimation of process vessels. *International Journal of Production Economics.* **112**(2), p 934-954.

31. Carr, R. I., 1989. Cost Estimating Principles. *Journal of Construction Engineering and Management*, **115** (4), p 545-551.

32. Chan, D. W.M. et al., 2011. An empirical survey of the motives and benefits of adopting guaranteed maximum price and target cost contracts in construction. *International Journal of Project Management.* **29**(5), p 577-590.

33. Chapman, J. R., 1997. Management, Washington, DC.

34. Chen, Q., Xia, B., Jin, Z., Wu, P. & Hu, Y., 2016. Choosing appropriate contract methods for design-build projects. *Journal of Management in Engineering,* **32**(1), p 7.

35. Chen, Q.W., Li, G.Y. & Zhuang, Q.H., 2009. The Analysis of Project Schedule Uncertainty: Based on Monte Carlo Simulation. *International Conference on* Management *and Service Science*. IEEE Conference Publications, p 1-4

36. Cheng, M.Y., Tsai, H.C., and Sudjono, E., 2010. Conceptual cost estimates using evolutionary fuzzy hybrid neural network for projects in construction industry. *Expert Systems With Applications.* **37**(6), p 4224-4231.

37. Chin, et al., (2008). *Handbook of Research on Contemporary Theoretical Models in Information Systems.* Dwivedi, Yogesh K. IGI Global

38. Chou, J.S., 2011. Cost simulation in an item-based project involving construction engineering and management. *International Journal of Project Management.* **29**(6), p 706(12).

39. Chua, D. K. H. & Godinot, M., 2006. Use of a WBS matrix to improve interface management in projects. (work breakdown structure). *Journal of Construction Engineering and Management.* **132**(1), p 67(13).

40. Cohen, L., Manion, L., Morrison, K, and Morrison, R.B., 2007. *Research methods in education*. Routledge.

41. Coombes, H., 2001. *Research using IT.* Basingstoke. Palgrave Study Skills.

42. Creswell J.W., 2013. *Qualitative inquiry & research design: choosing among five approaches.* 3rd ed. Thousand Oaks, Calif. London: SAGE.

43. Daschbach, J.M. and Apgar, H., 1988. Design Analysis through techniques of parametric cost estimating. *Journal of Parametrics.* **7**(2), p 87-93.

44. De Souza, A. D. et al., 2015. A Proposal for the Improvement of Project's Cost Predictability Using Earned Value Management and Historical Data of Cost - An Empirical Study. *International Journal of Software Engineering and Knowledge Engineering,* **25**(01), p 27.

45. DeWalt, Kathleen M. & DeWalt, Billie R., 1998. Participant observation. In H. Russell Bernard (Ed.), *Handbook of methods in cultural anthropology.* Walnut Creek: AltaMira Press.

46. Doloi, H. K., 2011. Understanding stakeholders' perspective of cost estimation in project management. *International Journal of Project Management.* **29**(5), p 622-636.

47. Doloi, H. K., 2014. Cost overruns and failure in project management: understanding the roles of key stakeholders in construction projects. *Journal of Construction Engineering and Management.* **139**(3), p 267(13).

48. Donald E. Parker, 2014. *Parametric Cost Modelling for Buildings.* 1st ed. Routledge.

49. Dudovskiy J., 2016. *The Ultimate Guide to Writing a Dissertation in Business Studies: A Step-by-Step Assistance*, July 2016. E-Book. Available: Research Methodology. Research-Methodology.net

50. Easterby-S, et al., 2012. Thinking through things. *Studies in History and Philosophy of Science Part A.* **43**(1) p 208-212.

51. Edum-Fotwe, F.T. and McCaffer, R., 2000. Developing project management competency: perspectives from construction industry. *International Journal of Project Management*. **18**, p 111-124.

52. Elias Sahle Advisor Prof, Dr. Ing. Abebe Dinku, 2016. *Review on Lack of Integration in Design and Construction Phases of Building projects and the Effect of Constructability.* A Case Study on Selected Public Buildings in Addis Ababa. School of Civil and Environmental Engineering. Addis Ababa University.

53. Enshassi, A., and Ayyash, A., 2014. Factors affecting cost contingency in the construction industry – contractors' perspective. *International Journal of Construction Management.* **14**(3), p 191-208.

54. Ethridge, D.E., 2004. *Research Methodology in Applied Economics.* John Wiley & Sons.

55. Fang, J. & Shu C., 2011. A Cross-platform integration design of the construction cost information resources in projects. *International Conference on Electric Technology and Civil Engineering.* IEEE Conference Publications. Lushan, China, p 5689-5693.

56. Fayard, D., Lee, L. S., Leitch, R. A. and Kettinger, W. J., 2012. Effect of internal cost management, information systems integration, and absorptive capacity on inter-organizational cost management in supply chains. *Accounting, Organizations and Society.* **37**(3), p 168-187.

57. Fellows, R. & Liu, A., 2009. *Research methods for construction*. 3rd ed. Dawsonera.

58. Ferry, J. D. & Brandon S.P., 1991. *Cost Planning of Buildings.* 6th ed. BSP Professional Books: Oxford.

59. Ferry, J. D., Brandon S.P. & Ferry D.J., 1999. *Cost Planning of Buildings*. 7th ed. Blackwell Science: Oxford.

60. Fincher, R. E., Wallach, P. M., & W Scott Richardson, 2009. Basic science right, not basic science elite: Medical education at a crossroad. *Journal of General Internal Medicine*. **24**(11), p 1255-1258.

61. Flick, U., 2006*. An introduction to qualitative research.* 3rd ed. London: Sage.

62. Forbes H. L. and Ahmed, S. M., 2011. *Modern Construction Lean Project Delivery and Integrated Practices*, Taylor and Francis: New York.

63. Forbes, L. H. & Ahmed, S. M., 2011. Modern construction: lean project delivery and integrated practices, Lean Construction Journal 2011.

64. GAO Cost Estimating and Assessment Guide, 2009*. Best Practices for Developing and Managing Capital Program Costs, GAO-09-3SP.* United States Government Accountability Office, March 2009, Preface.

65. Garg, A., Ghosh, D., Hudick, J. and Nowacki, C., 2003. Roles and Practices in Management Accounting Today. *Strategic Finance.* **85**, p 30-35.

66. Gibbs, G R, 2002. *Qualitative Data Analysis: Explorations with NVivo*. Buckingham: Open University Press.

67. Gill, J. and Johnson, Ph., 2002. *Research methods for managers*. 3rd ed. London: Sage.

68. Gillet, M., 2015. Effective Cost Estimating Strategy in Construction Project Management, In: Blog, [Viewed: 15 December, 2016]. Available: http://www.aproplan.com/blog/news/effective-cost-estimating-strategy-in-construction-project-management.

69. Glad, E. & Becker, H., 1996. *Activity Based Costing and Management.* John Wiley.

70. Glass V. G., Hopkins D. K., 1984. *Statistical methods in education and psychology*. Prentice-Hall.

71. Goddard, W and Melville, S., 2004. *Research Methodology: An Introduction*. Lansdowne: Juta and Company Ltd 6. Redman, L. V & Mory, A. V. H. (2009). The Romance of Research. Baltimore: The Williams & Wilkins Co.

72. Gray D.E., 2009. *Doing Research in the Real World*. 2nd ed. Thousand Oaks, California: Sage Publications.

73. Gray, W., 2009. Introduction to Volume 1, Issue 2 of topics. *Topics in Cognitive Science*, **1**(2), p 215

74. Griffith A., 2006. Scheduling Practices and Project Success, *Cost Engineering*, **48** (9), p 24.

75. Gu, X., Geng, Z. Xu, Wenxing Z. and Qunxiong, 2011. Hierarchy probability cost analysis model incorporate MAIMS principle for EPC project cost estimation. *Expert Systems With Applications*. **38**(7), p 8087-8098.

76. Guimaraes, F., 2000. *Research: Anyone Can Do It.* E- Book. Pedia Press. Available from: https://pediapress.com

77. Haga, W. A. & Marold, K. A., 2004. A simulation approach to the PERT/CPM time-cost trade-off problem. *Project Management Journal.* **35**(2), p 31(7).

78. Hanid M., Koskela L., Siriwardena M., 2011. *Traditional Cost Management vs. Lean Cost Management*. School of the Built Environment, University of Salford. Available from: https://www.academia.edu

79. Hanid, M., Siriwardena, M., and Koskela, L., 2011. What are the big issues in cost management? Paper presented at the *19th Annual Conference of the International Group for Lean Construction.* Lima, Peru.

80. Hassanein, A., and Moselhi, O., 2014. Planning and scheduling highway construction. *Journal of Construction Engineering and Management,* **130**(5), p 638(9).

81. Hegazy, T. and Moselhi, O., 1995. Elements of cost estimation: A survey in Canada and the United States. *Cost Engineering.* **37** (5), p 27-31.

82. Hendrickson C., 1998. *Project management for Construction*. 2nd ed. Prentice Hall.

83. Hendrickson C., 2008. Effects of Project Risks on Organization, *PM Hut Project Management for Construction.*

84. Hollar, D. A., Rasdorf, W., Liu, M., Hummer, J. E., Arocho, I. and Hsiang, S. M., 2013. Preliminary engineering cost estimation model for bridge projects. *Journal of Construction Engineering and Management.* **139**(9), p 1259(9).

85. Horgren, C.T., Foster, G. and Sikant, M.D., 1990. *Cost Accounting: a managerial emphasis.* 7th ed. Englewood: Prentice-Hall, p 964.

86. Horngen, C. T., 1989. Cost and management accounting: yesterday and today. *Journal of Management Accounting Research.* **1**, p 21-32.

87. Horngren C. T. et al., 2010. *Introduction to Management Accounting*. 15 ed. Pearson.

88. Howell A. G., 1999. “What is Lean Construction”, *Proceedings IGLC-7*, 26-28 July 1999, University of California, Berkeley CA, USA.

89. Hunter, K. and Kelly, J., 2008. *Grounded Theory, In: Knight, A. and Ruddock, L. Advanced research methods in the built environment.* Chichester, UK: Wiley-Blackwell.

90. Hurk, M., 2016. Learning to contract in public-private partnerships for road infrastructure: recent experiences in Belgium. *Policy Sciences, 2016.* **49**(3), p 309(25).

91. Industrial Research Institute 2010. *Research management.* Michigan: Industrial Research Institute

92. Innes, J., Mitchel, F. & Sinclair, D., 2000. Activity-based costing in the U.K.'s largest companies: a comparison of 1994 and 1999 survey results. *Management Accounting Research.* **11**(3), p 349-362.

93. Jackson L. S., 2012. *Research Methods and Statistics: A Critical Thinking Approach*. Cengage Learning.

94. Jallow A.K., Demian P., Baldwin, A. N. & Anumba C. J., 2014. An empirical study of the complexity of requirements management in construction projects. *Engineering, Construction and Architectural Management.* **21**(5).

95. James McCormick, 2001. "Scientific medicine—fact of fiction? The contribution of science to medicine". Occasional Paper (Royal College of General Practitioners) (80)

96. Jiang, Z., & Liu, X., 2011. Notice of Retraction Applied research of project management in sustainable development. In: *International Conference on Electric Technology and Civil Engineering,* IEEE Conference Publications. Lushan, China. **3**, p 1070-1075.

97. Jianyun, Y. 2011. Application of ABCM to Construction Project, In: International Conference on Information Management. *Innovation Management and Industrial Engineering*. Shenzhen, China. **1**, p 205-208.

98. Jrade, A. and Alkass, S., 2002. An integrated system for conceptual cost estimating of building projects. *Cost Engineering*. **44** (10), p 28.

99. K. Sunil, C.P. Pathirage and J. Underwood, 2015. The Importance of Integrating Cost Management with Building Information Modeling (BIM), *Conference or Workshop Item.* School of the Built Environment, University of Salford, Manchester.

100. Kaka, A. & Price, A. D. F., 1991. Relationship between value and duration of construction projects. *Construction Management and Economics.* **9,** p 383-400.

101. Kang B. G., Thorpe T. and Fotwe F. T. E., 2006. A managed approach to ethical decision making on construction projects. *CIQ Paper 202, CIOB, Englemere*, **8**(2).

102. Kaplan, R. S., 1984. Yesterday's accounting undermines production. *Harvard Business Review.* Harvard Business School Publication Corp.

103. Keith Potts, 2008. *Construction Cost Management Learning from case studies*. Taylor & Francis

104. Kern, A. P., & Formoso, C. T., 2004. Guidelines for Improving Cost Management in Fast-Complex and Uncertain Construction Projects. *Paper presented at the IGLC-12.* Copenhagen, Denmark 2004.

105. Khamidi M. F., Khan W. A. and Idrus A., 2011. The Cost Monitoring of Construction Projects Through Earned Value Analysis. *International Conference on Economics and Finance Research*, *IPEDR*, IACSIT Press, Singapore (**4**).

106. Kibler, B. E., 1992. Integrated Cost and Schedule Control: a piece of cake. *Cost Engineering*. **34** (7).

107. Kim, C. S. and Liu, L. Y., 2007. Cost information model for managing multiple projects. *Journal of Construction Engineering and Management.* **133**(12), p 966(9).

108. Kim, H.J., Seo, Y.C. & Hyun, C.T., 2012. A hybrid conceptual cost estimating model for large building projects. *Automation in Construction.* **25**, p 72-81.

109. Kim, Y. (2002). *The implications of a new production paradigm for a project control.* Berkeley: University of California.

110. King, R. T., Miles D. L., 2000. *Value engineering: theory and practice in industry*. Washington, D.C.: Lawrence D. Miles Value Foundation.

111. Kinsella M.S., 2002. Activity-based costing: Does it warrant inclusion in a Guide to Project Management Body of Knowledge PMBOK Guide. *International Journal of Project Management* **33**(2), p 49.

112. Koskela, L., 2000. An exploration towards a production theory and its application to construction. *Technical Research Centre of Finland – VTT.* Helsinki. Laufer, A. and Tucker, R.L. 1987.

113. Kothari, C. R., 2004. *Research Methodology, Methods and techniques.* 2nd ed. New age International Ltd.

114. Kumar S., 2005. *New Product Development, An Empirical Study of the Effects of Innovation Strategy, Organization Learning, and Market Conditions.* Springer Science & Business Media.

115. Langford, D. A., Kennedy, P., Conlin, J., and Mckenzie, N., 2003. Comparison of construction costs on motorway projects using measure and value and alternative tendering initiative contractual arrangements. *Construction Management and Economics.* **21**(8), p 831-840.

116. Lastra, G. de S. Adey, B. and Tyrone B., 2014. *Methodology to make accurate preliminary estimates of construction material quantities for construction projects.* Doctoral Thesis, University of Zurich.

117. Law, C., 1994. Building Contractor Estimating: British Style, *Cost Engineering.* **36**, p 23-28.

118. Lee, S.K. & Yu, J.H., 2012. Success model of project management information system in construction. *Automation in Construction.* **25**, p 82-93.

119. Lenferink, S., Tillema, T. and Arts, J., 2013. Towards sustainable infrastructure development through integrated contracts: Experiences with inclusiveness in Dutch infrastructure projects. *International Journal of Project Management.* **31**(4), p 615(13).

120. Liberatore, M. J. and Pollack-Johnson, B., 2013. Improving Project Management Decision Making by Modelling Quality, Time, and Cost Continuously. *IEEE Transactions on Engineering Management.* **60**(3), p 518-528.

121. Liu, Y., van Nederveen, S. & Hertogh, M., 2013. Understanding effects of BIM on collaborative design and construction: An empirical study in China. *International Journal of Project Management*. **35**(4).

122. Long J.A., 2000. *Parametric Cost Estimating in the New Millennium*. PRICE Systems.

123. Long, L. D. and Ohsato, A., 2009. A genetic algorithm-based method for scheduling repetitive construction projects. *Automation in Construction.* **18**(4), p 499-511.

124. Lopez, R. and Love, P. E. D., 2012. Design error costs in construction projects. *Journal of Construction Engineering and Management.* **138**(5), p 585(8).

125. Luo, S., Lu, Y., Le, Y. and Peng, Y., 2011. Design of integrated cost and contract management information systems for mega project. *International Conference on E-Business and E-Government.* IEEE Conference Publications.

126. Maciaszek, L. A., 2007. *Requirements Analysis and System Design*. 3rd ed. Harlow: Addison-Wesley.

127. Marshall, C., & Rossman, G. B., 1995. *Designing qualitative research*. Newbury Park, CA: Sage.

128. Maskell, B. H., 2009. *Making the Numbers Count: The Accountant as Change Agent on the World Class Team.* New York, Productivity Press.

129. Masschelein, S., Cardinaels, E. & Van Den Abeele, A., 2012. ABC information, fairness perceptions, and interim negotiations. *Accounting Review.* **87**(3), p 951(23).

130. Mättö, T. & Sippola, K., 2016. Cost Management in the Public Sector: Legitimation Behaviour and Relevant Decision Making. *Financial Accountability & Management.* **32**(2), p 179-201.

131. Mawby, D. and Stupples, D., 2002. Systems thinking for managing projects. *IEEE International Engineering Management Conference.* **1**. IEEE Conference Publications, p 344-349.

132. McCaffer, R. and Baldwin, A.N., 1984. Implementation of computer aided estimating systems in construction companies. A paper invited by the *Engineering Management Board for publication in the Proceedings of the Institution of Civil Engineers*. Proc. ICE Part 1, p 236-248.

133. McCaffer, R. McCaffrey, M.J. and Thorpe, A., 1984. Predicting the tender price of buildings during early design: method and validation. *Journal of the Operational Research Society.* **35** (5), p 415-423.

134. McCaffer, R., McCaffrey, M.J. and Thorpe, A., 1983. The disparity between construction cost and tender price movements. Based on work done for the Building Research Establishment. Construction Papers, the *Proceedings of the Chartered Institute of Building*. **2** (1), p 17-28.

135. McCaffer, R., Sher, W.D. and Gellatley, G., 1983. Estimators data and Standard Methods of Measurement. Based on work already reported to NRDC Construction Papers, Proc. of the Chartered Institute of Building. **2** (2), p 37-46.

136. Meadati, P., 2009. BIM Extension into Later Stages of Project Life Cycle. *Paper presented at the International conference of the 45th Annual ASC Conference.* Gainesville, Florida, US. ASC. http://ascpro.ascweb.org/chair/paper/CPRT102002009.pdf

137. Melin, B. J, Jr., 1994. Parametric Estimation. *Cost Engineering.* **36,** p 19.

138. Membah, J. and Asa, E., 2015. Estimating cost for transportation tunnel projects: a systematic literature review. *International Journal of Construction Management,* **15**(3), p 196-218.

139. Migliaccio, G.C., Zandbergen, P. & Martinez, A.A., 2015. Empirical comparison of methods for estimating location cost adjustments factors. *Journal of Management in Engineering.* **31** (2), p 10.

140. Monsey, A., 1997. A philosophical review of cost estimating. *Cost Engineering*, **39** (2). p 9.

141. Narbaev, T. and De Marco, A., 2014. An earned schedule-based regression model to improve cost estimate at completion. *International Journal of Project Management.* **32**(6), p 1007(12).

142. Narbaev, T. and Marco, A. D., 2011. Cost Estimate at Completions Methods in Construction Projects. *International Conference on Construction and Project Management.* IPEDR, IACSIT Press, Singapore. **15**.

143. Navon, R., 1995. Resource-based model for automatic cash-flow forecasting. *Construction Management and Economics.* **13,** p 501-510.

144. NBS., 2014. National BIM Report 2014. London: The NBS.

145. Walliman, N. M., 2006. *Social research methods.* London: Sage Publications, p 231.

146. Ntuen, C.A. and Mallik, A.K., 1987. Applying artificial intelligence to project cost estimating. *Cost Engineering*. **29**(5), p 9-13.

147. Olawale, Y. and Sun, M., 2015. Construction project control in the UK: Current practice, existing problems and recommendations for future improvement. *International Journal of Project Management.* **33**(3). P 623-637.

148. Oliver, V., 2010. *301 Smart Answers to Tough Business Etiquette Questions.* Skyhorse Publishing: New York USA.

149. Ostrenga, M. et al., 1997. *Guia da Ernst & Young para gestao total dos custos.* 13rd ed. Rio de Janeiro: Record.

150. Paraskevopoulou, C. & Benardos, A., 2013. Assessing the construction cost of Greek transportation tunnel projects. *Tunnelling and Underground Space Technology incorporating Trenchless Technology Research.* **38,** p 497-505.

151. Parker, D.E., 1993. Project budgeting for buildings, *Transactions of AACE International*. **37**, p 14(1).

152. Pennanen A., Ballard G. and Haahtela Y., 2011. Target costing and designing to targets in construction. *Journal of Financial Management of Property and Construction.* **16**(1), p 52-63.

153. Phaobunjong, K. and Popescu, C.M., 2003. Parametric cost estimating model for buildings. *AACE International Transactions*, 2003.

154. Plossl, G. W., 1990. *Cost accounting in manufacturing: dawn of a new era. Production Planning and Control*. Taylor & Francis.

155. Project Management Institute 2008. *A Guide to the Project Management Body of Knowledge (PMBOK® Guide)* – 4th ed.

156. Popham, K., 1996. Cost estimating using historical costs. *Transactions of AACE International,* 1996.

157. Project Management Institute (1996), 130 South State Road, Upper Darby, PA 19082 USA.

158. Project Management Institute. 2013. *Guide to the Project Management Body of Knowledge Guide (PMBOK).* 5th ed. Project Management Institute.

159. Punch, K., 2014. *Introduction to social research: quantitative & qualitative approaches.* 3rd ed. Los Angeles: SAGE.

160. Qazi, A., Quigley, J., Dickson, A., & Kirytopoulos, K., 2016. Project Complexity and Risk Management (ProCRiM): Towards modelling project complexity driven risk paths in construction projects. *International Journal of Project Management.* **34**(7), p 1183-1198.

161. Qiu, L. D. & Wang, S., 2011. BOT projects: Incentives and efficiency. *Journal of Development Economics.* **94**(1), p 127-138.

162. Reich, Y., 1994. Layered models of research methodologies. *Artificial Intelligence for Engineering, Design, Analysis and Manufacturing,* 1994. **8**(4), p 261-262.

163. RICS guidance note, 2015. *BIM for cost managers: requirements from the BIM model.* 1st ed. Royal Institution of Chartered Surveyors (RICS)

164. Robson, C., 2011. *Real world research: a resource for users of social research methods in applied settings.* 3rd ed. Chichester: John Wiley.

165. Roll-Hansen, N., 2009. Why the distinction between basic (theoretical) and applied (practical) research is important in the politics of science. *The London School of Economics and Political Science*. London,

166. Rupen, S., 2009. Tools Used to Estimate Costs in Project Management. [Viewed: 2011, October 10]. Available: http://www.brighthub.com/office/project-management/articles/54986.aspx

167. Salem, O., Solomon J., Genaidy, A., and Minkarah, I., 2006. Lean Construction: From Theory to Implementation, *Journal of Management in Engineering ASCE.* **22**(4).

168. Saravi, M. E., Newnes, L. B., Mileham, A. R. & Goh Y. M., 2008. Estimating cost at the conceptual design stage to optimize design in terms of performance and cost. In *the proceedings of the 15th ISPE International Conference on Concurrent Engineering.*

169. Saunders M., Adrian Thornhill, A., & Lewis P., 2009. *Research Methods for Business*. Students Paperback

170. Saunders, M., Lewis, P. & Thornhill, A., 2012 *Research Methods for Business Students*. 6th ed. Pearson Education Limited.

171. Schmuck, Richard., 1997. *Practical action research for change*. Arlington Heights. Skylight Training and Publishing.

172. Shields, Patricia and Rangarjan, N., 2013. *A Playbook for Research Methods: Integrating Conceptual Frameworks and Project Management*. Stillwater. New Forums Press.

173. Shillnglaw, G., 1989. Managerial cost accounting: present and future. *Journal of Management Accounting Research.* **1,** p 33-46.

174. Siami-Irdemoosa, E., Dindarloo, S. R. and Sharifzadeh, M., 2015. Work breakdown structure (WBS) development for underground construction. *Automation in Construction.* **58, p 85**(10).

175. Simmons, L.F., 2002. Project management-critical path method (CPM) and PERT simulated with Process Model. *Proceedings of the Winter Simulation Conference.* IEEE Conference Publications **2,** p 1786-1788.

176. Simpson, L., 2011. Estimates - a black art: how do you determine if a project is feasible before moving forward with the process design and construction phases? *Chem. Information.* **49**(2), p 19(1).

177. Singh, K., 2007. *Quantitative Social Research Methods.* SAGE Publications.

178. Skitmore, M., and Wilcock, J., 1994. Estimating Processes of Smaller Builders, *Construction Management and Economics*. **12**, p 139-154.

179. Skoyles, R., 1965. Operational bills: a critical appreciation. *The Quantity Surveyor*. **21** p 117-120.

180. Soetanto. R., Andrew R.J., Dainty A.R.J., Jacqueline Glass J. & Price A. D.F., 2006. *Towards an explicit design decision process: The case of the structural frame.* Construction Management and Economics. **24** (6).

181. Soibelman, L., Sacks, R., Akinci, B., Dikmen, I., Birgonul, M. T. and Eybpoosh, M., 2011. Preparing civil engineers for international collaboration in construction management. *Journal of Professional Issues in Engineering Education and Practice.* **137**(3), p 141(10).

182. Sonmez, R., 2005. Review of Conceptual Cost Modelling Techniques. *AACE International Transactions ABI/INFORM Research.* **31** (4).

183. Spicer, B. H., 1992. The resurgence of cost and management accounting: a review of some recent developments in practice, theories and case research methods. *Management Accounting Research.* **3,** p 1-37.

184. Stanford, M. S., Molenaar, K. R. and Sheeran, K. M., 2016. Application of indefinite delivery-indefinite quantity construction strategies at the federal level. *Journal of Management in Engineering*. **32**(5), p 11.

185. Staub S, Fisher M, Kunz J and Paulson B., 2003. A generic Feature activity-based cost estimation process. *Journal of Advanced Engineering Informatics*. **17**, p 23-39.

186. Stephen E. Mueller, CCE 2000. Resolving Work Breakdown Structure Problems. *AACE International Transactions ABI/INFORM Research.* **23** (2), p 677-680.

187. Stevens, S. S., 1946. On the Theory of Scales of Measurement. Science. **103**.

188. Theodorakopoulos T., Pasquire C.L. & Fitsilis P., 2009. Investigating a new Integrated Cost Management System within a Project Delivery', *Proceedings RICS COBRA 2009 Research Conference*, Sept. 10-11 2009, Royal Institution of Chartered Surveyors, University of Cape Town, South Africa, p 165-180.

189. Theodorakopoulos T., Pasquire C.L. & Fitsilis P., 2012. An Integrated Cost Management System for Construction Project Delivery', *Proceedings RICS COBRA 2012 Research Conference*, Sept. 11-13 2012, Royal Institution of Chartered Surveyors, Arizona State University, Las Vegas, Nevada U.S.A

190. Thorpe A, Tah J and McCaffer R., 1992. A knowledge based decision support system for drainage cost estimating. *The International Journal of Construction Information Technology*. **1** (1), p 11-28.

191. Thurairajah, N., & Goucher, D., 2013. Advantages and Challenges of Using BIM: A Cost Consultant's Perspective. Paper presented at the *49th ASC Annual International Conference.*

192. Turner, J. R., 1993. *The handbook of project based management: improving the process for achieving strategic objective*. McGraw-Hill, England.

193. Tzvi Raz and Elnathan, D., 1998. Activity Based Costing for projects. *International Journal of Project Management*. **17**(1), p 61-67.

194. Uher, T.E., 1996. "A probabilistic cost estimating model. *Cost Engineering.* **38**(4), p 33.

195. Uppal, K.B., 1997. Estimating? Past, present and 21st century. *AACE International Transactions*, p 118.

196. Uppal, K.B., 2001. Easy Factored Estimating and Process Cost Engineering. *AACE International Transactions,* 2001, p ES61.

197. User's Guide, European Commission. Directorat- e-General for Regional Policy and Cohesion, European Commission, 1998. *Understanding and Monitoring the Cost-determining Factors of Infrastructure Projects.*

198. Ustinovičius, D. Migilinskas, J. Tamošaitienė, E. Zavadskas, K., 2004. Uncertainty Analysis In Construction Project's Appraisal Phase L. *Automation in Construction.* **13**(2).

199. van Vuuren, D. P. et al., 2009. Comparison of top-down and bottom-up estimates of sectoral and regional greenhouse gas emission reduction potentials. *Energy Policy.* **37**(12), p 5125-5139.

200. Vojinovic, Z., Seidel, R. & Kecman, V., 2000. Advanced cost estimating and strategic planning. *AACE International Transactions*, 2000, p ES64.

201. Watkins, D., 2014. *Cost Control and Management, RIBA Part 3 Course Material* [Online]. [Viewed: 20/11/2016] Available: https://www.architecture.com/RIBA/Assets/Files/Part3docs/April/Spring%20Lecture%20Notes%20DXBHK/CostManagementandControl-DavidWatkins.pdf

202. Wilson, J., 2010. *Essentials of Business Research: A Guide to Doing Your Research Project*. SAGE Publications

203. Winston, T., 1997*. Introduction to Case Study*. The Qualitative Report. **3**(2).

204. Wu, S., Wood, G., Ginige, K., & Jong, S., 2014. *A technical review of BIM based cost estimating in UK quantity surveying practice, standards and tools.* Journal of Information Technology in Construction. **19**, p 534-562.

205. Yin, R.K., 1984. *Case Study Research: Design and Methods*. Sage Publications.

206. Zaidah Z., 2007. Case study as a research method, *Jurnal Kemanusiaan*. 9.

BIBLIOGRAPHY

Jrade, A. & Alkass, S. 2001, "A conceptual Cost Estimating Computer Program for Building Projects", *AACE International Transactions,* p IT91.

Project Management Institute. 2000. *Guide to the Project Management Body of Knowledge Guide (PMBOK),* 3rd edition, New York: Project Management

Ahcom, J., Uddin, S. & Shash, A.A. 2006, "A Pragmatic Setup for Cost Estimation", *AACE International Transactions,* p ES261.

Ahcom, J., Uddin, S. & Shash, A.A. 2006, "A Pragmatic Setup for Cost Estimation", *AACE International Transactions,* pp. ES261. Bognar, E. & Schoenbauer, C. 1999, "Multi-project costing and reporting techniques", *AACE International Transactions,* pp. V41.

Cobb, R.A., Elliott, D.P. & American Association of Cost Engineers 1989, Cost estimating: techniques and applications, *American Association of Cost Engineers*, Morgantown, WV.

Creese, R.C. 2002, "Estimating construction costs", *Cost Engineering*, 44(11), p 36.

De la Garza, Jesus M. & Rouhana, K.G. 1995, "Neural networks versus parameter-based applications in cost", *Cost Engineering*, 37(2), p14.

"Estimator: An application of variable precision logic to construction cost estimation: Peter Haddawy and Jim Kelly Intelligent Systems Group, Department of Computer Science, University of Illinois", 1987, *Artificial Intelligence in Engineering,* vol. 2, no. 2, pp. 119-278.

Fellows, R.; Liu, A. 2008, *Research methods for construction,* 3rd Edition, Blackwell, Oxford.

Fleming, Q.W. & Koppelman, J.M. 1997, "Earned value project management", *Cost Engineering*, 39(2) 13.

Grennberg T. 1994, “Project types in building and construction”, *International Journal of Project Management*, 11(2), p 68-71.

Jorgensen, B. and Emmitt, S. 2009. Investigating the integration of design and construction from a "lean" perspective. *Construction Innovation: Information, Process, Management.* 9, p 225-240.

Morris P. G., 1994. *The Management of Projects* Thomas Telford

O Brien, M.J. & Pantouvakis, J.P. 1993, "A new approach to the development of computer-aided estimating systems for the construction industry", *Construction Management and Economics*, 11(1), p 30.

Perera, A D A J. & Imriyas, K. 2004. An integrated construction project cost information system using MS Access and MS Project. *Construction Management and Economics*, 22 (2), p. 203.

Project Management Institute. 2008. *Guide to the Project Management Body of*

Knowledge Guide (PMBOK), 4th edition, New York: Project Management Institute

Raz, T. and Elnathan, D. 1999. Activity based costing for projects. *International Journal of Project Management*, 17 (1), p 61-67.

Samid, G. 1997. Activity-Based Cost Management: Making It Work. *Cost Engineering*. **39** (10).

Sergio and, A. and Conte, I., 2002. Lean Construction: From Theory To Practice Proceedings IGLC-10, August 2002. Gramado, Brazil.

Singh, A. 2007. Approximate Estimating Method for Typical Buildings. *Cost Engineering*. **49** (8).

Smith, J., 2000. *Cost Planning of Buildings Construction. Management and Economics*. **18** (4).

Sutherland, J., 1999. Project cost estimating for major renovation projects, *AACE International Transactions*, 1999.

APPENDIX 1: RICS COBRA Research Conference, University of Cape Town Mr. Thomas Theodorakopoulos 2009

RICS COBRA Research Conference, University of Cape Town, 10-11th September 2009. "INVESTIGATING A NEW INTEGRATED COST MANAGEMENT SYSTEM WITHIN A LEAN PROJECT DELIVERY SYSTEM". AUTHOR: MR THOMAS THEODORAKOPOULOS, pp 165-180. **ISBN No:** 978-1-84219-519-2

Thomas Theodorakopoulos

From: T.Theodorakopoulos@lboro.ac.uk
Sent: Thursday, July 16, 2009 9:51 AM
To: ttheodorakopoulos@jp-avax.gr
Subject: FWD:RE: Acceptance of paper - COBRA 2009

Thomas

This bounced back on Saturday - let me know if this arrives.

Best wishes

Stephen Brown
Head of Research
RICS
12 Great George Street
London SW1P 3AD
United Kingdom

T +44 (0)20 7334 3725
F +44 (0)20 7334 3894
E sbrown@rics.org
W rics.org
View details of RICS research at www.rics.org/researcharchive

RICS - The mark of property professionalism worldwide
12 Great George Street, Parliament Square, London SW1P 3AD, UNITED KINGDOM

From: Brown Stephen
Sent: 11 July 2009 17:20
To: 'T.Theodorakopoulos@lboro.ac.uk'
Subject: Acceptance of paper - COBRA 2009

Thomas

Your paper, "Investigating a new integrated cost management system within lean project delivery" has now been assessed for COBRA 2009 and, subject to amending your paper in accordance with the points made by the referees, the paper is accepted for presentation. You are invited to prepare a final version of your paper which responds to the following points made by the referees, which are as follows:

1. *The paper begins quite well and states its objectives clearly but, unfortunately, loses that clarity as the argument unfolds. The author(s) should re-visit their primary objective, outlining a framework within which a proposed cost management system will be developed using lean processes as a platform, and look to the latter part of the paper as a place to develop this objective.*

1

2. *The language of the paper, again, begins quite coherently but then seems to break apart as the paper continues. For example, section 2.2 seems to be a list of items as separate sentences that could easily be written as bullet points.*
3. *Section 3 titled research methodology does not contain a research methodology, it contains research steps. Hence, "we did this, then this, then this" is appropriate when in the context of a methodology that supports these claims for an appropriate direction of the work. If the methodology is literature review and consolidation, as it seems, then the methodology needs to address this direction. If not, how are you investigating and validating your ideas?*
4. *As with the writing, the tables and figures seem to make less sense as the paper moves along. There seems to be a figure between Figure 1 and Figure 2, but this is not clear. Figure 2 starts with number 2, but maybe number 1 was misplaced in the mysterious figure? This reviewer cannot make sense and therefore provide constructive feedback.*
5. *Figure 2 contains large columns with much information. Please consider separating these into areas and write about the definitions of your organization and terms. It will add to the clarity of how Lean design, supply and assembly fit. This reviewer also would need more explanation as to the meaning or definition of the "lean(s)" arrows across the bottom.*
6. *Figure 3 is too small to read. This diagram, as a major part of the work, should be displayed more prominently and explained thoroughly. One source is cited at the top of the mode design process section. Are there no other sources for the different columns or rows?*
7. *Table 1: please explain the "author's projects' archive). How is it relevant to this study?*
8. *Table 2: The description of this table and the algorithm used are difficult to understand and do not add to the value of the paper at this point. Please be explicit as to your reason for including such methods and make sure the table reinforces an ease to viewing these data.*

I would be grateful if you could send me your final paper by no later than 14 August, for inclusion in the conference proceedings.

I would also stress that you and all other co-authors now need to register for the conference, if you have not already done so. This can be done at:

http://www.uct-cmc.co.za/Conferences/conf-main.asp?Conf_ID=97&Page=Home

I look forward to meeting to in Cape Town

Best wishes

Stephen Brown
Head of Research
RICS
12 Great George Street
London SW1P 3AD
United Kingdom

2

T +44 (0)20 7334 3725
F +44 (0)20 7334 3894
E sbrown@rics.org
W rics.org
View details of RICS research at www.rics.org/researcharchive

RICS - The mark of property professionalism worldwide
12 Great George Street, Parliament Square, London SW1P 3AD, UNITED KINGDOM

Think before your print!

3

COBRA-The RICS Construction and
Bldg Research Conference

c/o UCT Conference Management Centre
Barnard Fuller Bldg,Anzio Rd,Observatory
Cape Town, 7925

Invoice

Tax Date	Invoice No.
2009/07/23	57

PAID

Invoice To
Theodorakopoulos, Thomas

P.O. Number

Description	Qty	Price	Amount
Registration Fee Delegate 2 Days Late		5,700.00	5,700.00

Total	R5,700.00
Balance Due	R0.00

Please pay directly into the following bank account using your surname or company name (trade) as reference. Fax a legible copy of proof of payment to 021 448 6263

Acc Name: "Conference Management 02"
Standard Bank
Mowbray 024909
Acc No: 071-278-850
Swift : SBZAZAJJ

PUBLICATION UPDATE FORM

Category:				
Printed: (Please tick)	**Cd Rom:** √	**Web:** √	**URL:** **www.rics.org/cobra**	
Title of Works:	The proceedings of COBRA 2009, the construction and building research conference of the Royal Institution of Chartered Surveyors			
Major Works:				
Volume No:		**Issue No:**		
Editors:	Stephen Brown (RICS) and Paul Bowen (University of Cape Town)			
Publisher:	RICS			
Publisher Town:	London, United Kingdom			
Conference:	COBRA 2009			
Venue:	University of Cape Town, Cape Town, South Africa			
Published:	**Day: 10**	**Month: September**	**Year: 2009**	
Page Numbers:	pp165-180			
ISBN No:	978-184219-519-2			
AUTHORS: (Please indicate whether staff, researchers or external co-authors)				
1)				
2)				
3)				
4)				
5)				

Investigating a new integrated cost management system within Lean Project Delivery

Mr Thomas Theodorakopoulos [1], Dr Christine L. Pasquire [2] and Prof. Dr Panos Fitsilis[3]

[1] eqm, Project & Construction Management firm,
Ippokratous 49, 26335 Patras,
Greece, EKPPT project.
[2]Civil & Building Engineering Department,
Loughborough University, Leics, LE11 3TU
United Kingdom
[3] Project Management Department,
Technological Education Institute of Larissa, TEI Larissa, 41110 Larissa,
Greece

Email: T.Theodorakopoulos@lboro.ac.uk; C.L.Pasquire@lboro.ac.uk; Fitsilis@teilar.gr

Abstract:
Construction projects have a specific set of objectives and constraints and project cost management is listed as one of core areas in which a project manager should be competent. Traditional methods of managing cost have been driven by the design of product and process, rather than serving as criteria for acceptable designs. Cost management has attempted to exert control after budgets are fixed and taking action to recover to targets. Very often, the organization which controls the cost is different from the organization which prepares the cost estimates, sometimes using different techniques and/or software. Lean Construction offers a new way to design and build that can finally release the traditional project team from the constraints of cost driven management and permit a fully integrated cost management system to be developed. The goal of this system will be to optimise performance across the whole process whilst achieving significant cost reductions. This paper outlines the framework within which the proposed cost management system will be developed using lean processes as a platform. The paper will also highlight the need for behavioural changes to support the system implementation

Keywords:
Cost management, Cost Control, Design management, Lean Construction, Lean Project Delivery, Project management

1 Introduction

In construction projects, significant uncertainty exists throughout the projects. Weather conditions, soil conditions, owner changes, and the interaction between multiple

APPENDIX 2: RICS COBRA Research Conference, Arizona State University, Las Vegas, USA. Mr. Thomas Theodorakopoulos 2012

RICS COBRA Research Conference, Arizona State University, 11-13th September 2012, Las Vegas, USA "An Integrated Cost Management System for Construction Project Delivery" Thomas Theodorakopoulos, Francis Edum-Fotwe and Christine L. Pasquire

RICS

RICS Cobra 2012
11-13 September 2012
Monte Carol Hotel, Las Vegas

Registration Confirmation
To be completed and retunred to cobra@rics.org by Wednesday 8 August

DELEGATE DETAILS	DELEGATE				ACCOMPANYING GUEST/S
Name (Fist name)	THOMAS				1 GUEST POSSIBLY
Surname (Family name)	THEODORAKOPOULOS				
Are you presenting a paper (please tick)	Yes	X	No		
If Yes, please conifrm the name of your paper	AN INTEGRATED COST MANAGEMENT SYSTEM FOR CONSTRUCTION PROJECT DELIVERY				
Organisation	LOUGHBOROUGH UNIVERSITY				
Address					
City	LOUGHBOROUGH				
Zip code/Postcode	Leics, UK, LE11 3TU				
Country	UK				
Telephone number					
Email address					
Are the details above the billing details for the invoice (please tick)	Yes		No	X	

If No, advise the details below:	
Orginisation	THOMAS THEODORAKOPOULOS
Addresss	IPPOKRATOUS 49
City	PATRAS
Zip code/Postcode	26332
Country	GREECE
Email addresss	thomastheodorakopoulos@yahoo.gr ttheodorakopoulos@jp-avax.gr

Please note that if the invoice is to be issued to a company, we will require the company VAT number (your invoice will not be processed until the company VAT number had been received)

Company VAT number	

Please advise if you or your accompanying guests have any specific dietary or access requirements

You	
accompanying guests 1	
accompanying guests 2	

Will accommodation be booked direct with the Monte Carlo Hotel (please tick)	Yes	X	No		**Please note: A $30 surcharge will be charged to attendees who do not stay at the host hotel.**

Invoice details

Delegate Fee		Number of places
RICS Cobra Delegate Fee (includes attendance at the opening drinks reception, attendance at the conference 11 – 13 September, attendance at the conference dinner, breakfast, lunch and refreshments during the conference and conference documentation)	$300	X
Accompanying guest fee - drinks reception	$50	
Accompanying guest fee - conference dinner	$100	
Accommodation surcharge	$30	
Total invoice amount		

On receipt of the completed form an invoice will be issued

RICS Conferences Terms and Conditions

On completion, this form represents a legally binding contract in which the following terms and conditions apply:

- This event is organised by RICS Conferences, a department of RICS.
- Payment is required within 7 days of receiving the invoice. Your booking is not confirmed until payment has been made.
- Confirmation of registration and receipted invoice will be sent in acknowledgement of all bookings.
- Cancellations must be made in writing and will be subject to a 20% administration charge, but no refunds can be made for cancellations notified within 30 days of the event.
- RICS Conferences is not liable for bank charges or any other costs incurred by delegates in attending the event.
- RICS Conferences accepts no responsibility for the views or opinions as expressed by the speakers, chairman or any other persons at the event.
- RICS Conferences checks the venues for accessibility. Please let us know if you have access or other requirements.
- RICS Conferences reserves the right to refuse entry to delegates if it chooses.
- RICS Conferences reserves the right to change the venue and/or speakers at any time and without prior notice.
- RICS Conferences also reserves the right in its absolute discretion to cancel the event.

2012 RICS COBRA
Las Vegas, Nevada USA
September 11-13, 2012

RICS COBRA 2012

AN INTEGRATED COST MANAGEMENT SYSTEM FOR CONSTRUCTION PROJECT DELIVERY

Thomas Theodorakopoulos[1], Francis Edum-Fotwe[2] and Christine L. Pasquire[3]

[1] *Civil Engineer MSc, Project manager- J&P AVAX S.A., Amarousiou Xalandriou 16, 15125 Athens, Greece, EKPPT project*

[2] *Lecturer in Construction Management Civil & Building Engineering Department, Loughborough University, Leics, UK, LE11 3TU*

[3] *Professor of Lean Construction, School of Architecture, Design and the Built Environment, Nottingham Trent University, Burton Street, Nottingham, Nottinghamshire, NG1 4BU*

ABSTRACT

Cost management is a major discipline in delivering construction projects of different sizes and complexity. Existing cost systems are mostly based on the principles of cost control in project delivery. Within such a control context, cost information is usually produced too late, and is often too aggregated and distorted for use in project management. A review of existing literature suggests that the main problems for the poor performance of traditional cost systems are related to flaws in estimating and cost control processes, inadequate information modelling, and more significantly, the lack of integration of cost management across the whole project. In addition, there is the problem of measurements provided by traditional cost systems not sufficiently linked to the goals and objectives set for each project. Traditional cost control processes are also criticized because they simply identify variances by monitoring actual performance against cost estimates. To address these inherent weaknesses in the current practice of cost management, a framework for an integrated system has been proposed. The proposed cost management system aims to cover the gaps of traditional methodology by integrating the stages in projects' whole life cycle. The current paper outlines the integration methodology that has been adopted in the proposed system. It covers the project stages from inception to use and operation stage. An alpha version of an applied model derived from the proposed integrated system is presented as a basis for future research.

Keywords: cost control, cost estimation, cost management, project delivery, project management.

[1] T.Theodorakopoulos@lboro.ac.uk
[2] F.T.Edum-fotwe@lboro.ac.uk
[3] christine.pasquire@ntu.ac.uk

COBRA 2012, Las Vegas

Legal Research Symposium

ABSTRACT

Abstracts should be submitted electronically to abstracts@cobra2012.com using this template by **Thursday 1st March 2012**

Abstract title (10 words maximum)	An Integrated Cost Management System for Construction Project Delivery	
Author(s)	**Thomas Theodorakopoulos[1], Francis Edum-Fotwe[2] and Christine L. Pasquire[3]** [1]*Civil Engineer MSc, Project manager- J&P AVAX S.A., Amarousiou Xalandriou 16, 15125 Athens, Greece, EKPPT project.* [2] *Lecturer in Construction Management Civil & Building Engineering Department, Loughborough University, Leics, UK, LE11 3TU* [3] *Professor of Lean Construction , School of Architecture, Design and the Built Environment, Nottingham Trent University, Burton Street, Nottingham, Nottinghamshire, NG1 4BU*	
Corresponding author	Thomas Theodorakopoulos	
Affiliation		
E-mail	Endnote	
Symposium theme (Please identify the most appropriate theme for your paper with an "X" in the right hand column)	Property Law	
	Construction Law	
	Environmental Law	
	Housing Law	
	Planning Law	
	Building Regulation & Control	
	Professional Liability & Ethics	
	Alternative Dispute Resolution	
	Legal Education in Property & Construction	
	International & Comparative Law	
Keywords (5 maximum)	Cost management, Cost Control, Project Delivery, Cost Estimation, Project management	
Abstract text (200 words maximum)	Cost management is a major discipline in delivering construction projects of different sizes and complexity. Existing cost systems are mostly based on the principles of cost control in project delivery. Within such a control context, cost information is usually produced too late, and is often too aggregated and distorted for use in project management. A review of existing literature suggests that the main problems for the poor performance of traditional	

[1] T.Theodorakopoulos@lboro.ac.uk

[2] F.T.Edum-fotwe@lboro.ac.uk

[3] christine.pasquire@ntu.ac.uk

	cost systems are related to flaws in estimating and cost control processes, inadequate information modelling, and more significantly, the lack of integration of cost management across the whole project. In addition, there is the problem of measurements provided by traditional cost systems not sufficiently linked to the goals and objectives set for each project. Traditional cost control processes are also criticized because they simply identify variances by monitoring actual performance against cost estimates. To address these inherent weaknesses in the current practice of cost management, a framework for an integrated system has been proposed. The proposed cost management system aims to cover the gaps of traditional methodology by integrating the stages in projects' whole life cycle. The current paper outlines the integration methodology that has been adopted in the proposed system. It covers the project stages from inception to use and operation stage. An alpha version of an applied model derived from the proposed integrated system is presented as a basis for future research.

RICS COBRA 2012

TRANSFER OF COPYRIGHT AGREEMENT

Registration fee must be paid and Copyright Agreement must be signed and returned to the editorial office before the paper can be published.

The Article Entitled: AN INTEGRATED COST MANAGEMENT SYSTEM FOR CONSTRUCTION PROJECT DELIVERY

Electronic signature is acceptable. Otherwise, sign and scan to cobra2012@pbsrg.com.

	31/07/2012
Signature	Date (mm/dd/yyyy)
Thomas Theodorakopoulos	Mr
Printed Name	Title
Loughborough University	
Institution/Company	

2012 RICS COBRA
Las Vegas, Nevada USA
September 11-13, 2012

AN INTEGRATED COST MANAGEMENT SYSTEM FOR CONSTRUCTION PROJECT DELIVERY

Thomas Theodorakopoulos[1], Francis Edum-Fotwe[2] and Christine L. Pasquire[3]

[1] *Civil Engineer MSc, Project manager- J&P AVAX S.A., Amarousiou Xalandriou 16, 15125 Athens, Greece, EKPPT project*

[2] *Lecturer in Construction Management Civil & Building Engineering Department, Loughborough University, Leics, UK, LE11 3TU*

[3] *Professor of Lean Construction, School of Architecture, Design and the Built Environment, Nottingham Trent University, Burton Street, Nottingham, Nottinghamshire, NG1 4BU*

ABSTRACT

Cost management is a major discipline in delivering construction projects of different sizes and complexity. In existing cost management systems information is usually produced too late, and is often too aggregated and distorted for use in project management. A review of existing literature suggests that the main problems for the poor performance of traditional cost systems are related to flaws in estimating and cost control processes, inadequate information modelling, and more significantly, the lack of integration of cost management across the whole project. In addition, problem of measurements provided by traditional cost systems not sufficiently linked to the goals and objectives set for project. Traditional cost control processes are also criticized because they simply identify variances by monitoring actual performance against cost estimates. To address these inherent weaknesses in the current practice of cost management, a framework for an integrated system has been proposed which aims to cover the gaps of traditional methodology by integrating the stages in projects' whole life cycle. The current paper outlines the integration methodology that has been adopted in the proposed system. It covers the project stages from inception to operation stage. An alpha version of an applied model derived from the proposed integrated system is presented as a basis for future research.

Keywords: cost control, cost estimation, cost management, project delivery, project management.

INTRODUCTION

Existing traditional cost management systems are mostly based on the same principles conducted ages ago. Cost information is usually produced too late, and it is too aggregated and too distorted to be relevant for project management. (Kern & Formoso 2004). An accurate estimation of construction cost is crucial in construction projects for budgeting, planning, and monitoring for compliance with the client's available budget, time and work outstanding. In cost estimation, the experience of the estimator and the project information are significant factors. Therefore, parametric cost

[1] T.Theodorakopoulos@lboro.ac.uk
[2] F.T.Edum-fotwe@lboro.ac.uk
[3] christine.pasquire@ntu.ac.uk

APPENDIX 3: RICS COBRA New Delhi, India Mr. Thomas Theodorakopoulos 2013

RICS COBRA 2013 New Delhi, India September 10-12, 2013 "An Integrated Cost Management System and applied model packages for Construction Project Delivery"

Thomas Theodorakopoulos, Francis Edum-Fotwe and Christine L. Pasquire

RICS COBRA 2013

Author(s)	Thomas Theodorakopoulos, Francis Edum-Fotwe, Christine L. Pasquire
Paper Title	An Integrated Cost Management System and Applied Model Packages for Construction Project Delivery

Please record your decision here

Accepted X	Accepted subject to comments below	Rejected

Note for Reviewer: Please record your comments/suggestions below (if any)

Aim and purpose	Clearly defined aim and purpose
Design and methodology	Clearly defined research design and methodology
Key findings and what they indicate	Clearly defined key findings.
Originality	An original piece of work. We look forward to the paper with interest.
Keywords and applicability to stream	Appropriate and applicable to the stream.

Reviewer's name	Henry Odeyinka
Date	14/02/13

RICS COBRA 2013

Cobra 2013: Paper Review Form

Author(s)	Theodorakopoulus et al.,
Paper Title	An integrated cost management system and applied model packages for construction project delivery
Reviewer's name	Dr Nigel Craig
Date	14th June 2013

Please record your decision here

Accepted	**Accepted subject to comments below**	Rejected

Notes for Reviewer: Record your comments/suggestions below (if any). Please bear in mind that comments will be shared with authors. Papers should be suitable for presentation at an academic conference and are not expected to be full journal papers.

Adherence to guidelines	Conforms to guidelines
Research methodology	Based upon a model.
Conclusion	Conclusions are weak and require re-writing. You state that the model has been analysed and the results from the main reports will be used as feedback'. What are these results? The conclusions do not 'conclude' the work.
General comments	Abstract – 'the current paper should read this paper? Page 2 – Kern and Formoso 2004 – not in the reference list Page 2 - full stop should come after the references Last line of introduction on page 2, please provide evidence to back-up 'today's approach' Drawbacks section – address the sentence structure at the beginning of this section Theodorakoupoulas 2009 and 2012 should both be at al., Page 2 – you state that major problems of cost management are poor performance and inadequate IMS, says who? Page 3 – structure of sentences at beginning of page 3 Page 3 – Full stop after reference

	Cost planning section – can you demonstrate because of the lack of references how different this paper is to the paper published at the 2012 conference? Bring in table 1 as close to the text as possible. Khamidi 2011 should be et al., Figures need to be brought into the text as near to the referral as possible. Have you enough discussion on the analysis of model development to justify 6 figures. Expand the size of tables so the reader can 'read' them. This paper has been a little rushed in its preparation. Some basic errors have been made. Nevertheless this is an under researched area and I am keen to see this QS based work published. Please address the concerns above.

2013 RICS COBRA
New Delhi, India
September 10-12, 2013

AN INTEGRATED COST MANAGEMENT SYSTEM AND APPLIED MODEL PACKAGES FOR CONSTRUCTION PROJECT DELIVERY

Thomas Theodorakopoulos[1], Francis Edum-Fotwe[2] and Christine L. Pasquire[3]

[1] Civil Engineer MSc, Project manager- J&P AVAX S.A., Amarousiou Xalandriou 16, 15125 Athens, Greece, EKPPT project

[2] Lecturer in Construction Management Civil & Building Engineering Department, Loughborough University, Leics, UK, LE11 3TU

[3] Professor of Lean Construction, School of Architecture, Design and the Built Environment, Nottingham Trent University, Burton Street, Nottingham, Nottinghamshire, NG1 4BU

ABSTRACT

Cost management is a major discipline in delivering construction projects of different sizes and complexity. Existing cost systems are mostly based on the principles of cost control in project delivery. Within such a control context, cost information is usually produced too late, and is often too aggregated and distorted for use in project management. A review of existing literature suggests that the main problems for the poor performance of traditional cost systems are related to flaws in estimating and cost control processes, inadequate information modelling, and more significantly, the lack of integration of cost management across the whole project. In addition, there is the problem of measurements provided by traditional cost systems not sufficiently linked to the goals and objectives set for each project. Traditional cost control processes are also criticized because they simply identify variances by monitoring actual performance against cost estimates. To address these inherent weaknesses in the current practice of cost management, a framework for an integrated system has been proposed which aims to cover the gaps of traditional methodology by integrating the stages in projects' whole life cycle. After a successful development of an alpha version of applied model, this paper outlines integration model packages of the complete integrated cost management system. Case studies from on current projects are also presented. The integration model packages synthesize the complete integrated model which is part of the total integrated cost management system for project delivery and determine the basis for a future research.

Keywords: cost control, cost estimation, cost management, project delivery, project management.

INTRODUCTION

Existing traditional cost management systems are mostly based on the same principles conducted ages ago. Cost information is usually produced too late, and its too

[1] T.Theodorakopoulos@lboro.ac.uk, thomastheodorakopoulos@yahoo.gr
[2] F.T.Edum-fotwe@lboro.ac.uk
[3] christine.pasquire@ntu.ac.uk

APPENDIX 4: SUBMISSION DESIGN FOLLOW- UP

Project: "Design, Construction, Financing, Operation, Maintenance and Exploitat
of Motorw

AWX 'S SUBMISSION FOLLOW UP - STRUCTURES' PRELIMINARY DESIGN

A/A	STR	DOCUMENT				SENT TO AWX	SENT TO CJV		SENT TO IEN				
		TITLE	ORIG	FIL	REV	(draft)	TRANS	COMMENTS	TRANS	PLANNED RETURN	RETURN IEN Prot. Nb	HARD COPY	STATUS
Design:	**UNDERPASSES**												
1	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX**	3TT	FIL KPX CON P 99267	A-		20-02-09 (AWX 09/0003)	-	24-02-09 (AKT 09/0230)	10-03-09	10-03-09 (BRD 787)	-	AKV/APC
2	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX**	3TT	FIL KP3 CON P 99246	A-		31-07-09 (AWX 09/0064)	-	05-08-09 (AKT 09/1179)	26-08-09	07-10-09 (BRD 2301)	14-10-09 (AKT 09/1774)	AKV/OTI
3	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX** (G.U. XX, CH: XXXKM)	3TT		DRAFT								
	» »	» » » »	» »		DRAFT								
	» »	» » » »	» »	FIL KP3 CON P 99266	A-		08-03-10 (AWX 10/0030)	10-03-10 (BRD 5505)	17-03-10 (AKT 10/0807)	07-04-10	19-04-10 (BRD 5506)	25-05-10 (AKT 10/1791)	AKV/OTI
4	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX**	3TT	FIL KP3 CON P 99242	A-		09-02-10 (AWX 10/0019)	16-02-10 (BRD 4959)	17-02-10 (AKT 10/0434)	10-03-10	16-03-10 (BRD 4939)	24-03-10 (AKT 10/0905)	AKV/OTI
5	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX**	3TT	FIL KP3 CON P 99243	A-		09-02-10 (AWX 10/0018)	16-02-10 (BRD 4958)	17-02-10 (AKT 10/0436)	10-03-10	26-03-10 (BRD 4944)	23-04-10 (AKT 10/1336)	AKV/OTI
6	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX** (G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99261	A-		07-06-10 (AWX 10/0076)	22-06-10 (BRD 7270)	21-06-10 (AKT 10/2315)	12-07-10	23-07-10 (BRD 7269)	26-08-10 (AKT 10/3518)	AKV/APC,A
7	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX** (G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99262	A-		07-06-10 (AWX 10/0077)	10-06-10 (BRD 7176)	15-06-10 (AKT 10/2200)	06-07-10	15-07-10 (BRD 7175)	05-08-10 (AKT 10/3147)	AKV/ NAP,APC,A
8	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX** (G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99263	A-		07-06-10 (AWX 10/0078)	10-06-10 (BRD 7173)	15-06-10 (AKT 10/2198)	06-07-10	19-07-10 (BRD 7174)	05-08-10 (AKT 10/3148)	AKV/API
9	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX** (G.U. XX, CH: XXXKM)	3TT		DRAFT	09-06-10 DRAFT R311 mail KAL							
	» »	» » » »	» »		DRAFT	10-06-10 mail TTA							
	» »	» » » »	» »		DRAFT	11-06-10 mail TTA							
	» »	» » » »	KAL		DRAFT	29-06-10 mail KAL							
	» »	» » » »	3TT		DRAFT	30-06-10 mail TTA							
	» »	» » » »	» »	FIL KP3 CON P 99244	A-		06-07-10 (AWX 10/0096)	07-07-10 (BRD 7582)	08-07-10 (AKT 10/2608)	29-07-10	09-08-10 (BRD 7581)	01-09-10 (AKT 10/3647)	AKV/APC,A
10	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX** (G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99250	A-		21-07-10 (AWX 10/0107)	27-07-10 (BRD 7839)	27-07-10 (AKT 10/2927)	17-08-10	03-09-10 (BRD 7840)		AKV/OTI
11	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX** ((G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99264	A-		03-08-10 (AWX 10/0115)	10-08-10 (BRD 8147)	13-08-10 (AKT 10/3255)	03-09-10	13-09-10 (BRD 8146)	16-09-10 (AKT 10/4042)	AKV/NAP,A
12	**KXXX**	**UNDERPASS KXXX (old KXXX)**	3TT		DRAFT	07-09-10 mail AW3							
	» »	» » » »	» »		DRAFT	06-10-10 mail TTA							
	» »	PRELIMINARY DESIGN OF **UNDERPASS KXXX** (G.U. XX, CH: XXXKM)	» »	FIL KP3 CON P 99247	A-		20-10-10 (AWX 10/0172)	22-10-10 (BRD 8975)	26-10-10 (AKT 10/4695)	16-11-10	24-11-10 (BRD 8974)	06-12-10 (AKT 10/5561)	AKV/APC,A
13	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX**((G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON K P 99251	A-		15-12-10 (AWX 10/0218)	16-12-10 (BRD 9890)	17-12-10 (AKT 10/5816)	07-01-11	27-01-11 (BRD 9889)	21-02-11 (AKT 11/1051)	AKV/APC,A
14	**KXXX**	PRELIMINARY DESIGN OF **UNDERPASS KXXX**(G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99255	A-		15-12-10 (AWX 10/0219)	-	17-12-10 (AKT 10/5817)	07-01-11	25-01-11 (BRD 9891)	14-02-11 (AKT 11/0844)	AKV/APC,A
15	**KXXX**	PRELIMINARY DESIGN OF UNDERPASS KXXX (G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99256	A-		15-12-10 (AWX 10/0220)	15-12-10 (BRD 9888)	17-12-10 (AKT 10/5816)	07-01-11	27-01-11 (BRD 9887)	21-02-11 (AKT 11/1053)	AKV/APC,A
16	**KXXX**	PRELIMINARY DESIGN OF UNDERPASS KXXX (G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99257	A-		15-12-10 (AWX 10/0221)	17-12-10 (BRD 9924)	20-12-10 (AKT 10/5851)	10-01-11	03-02-11 (BRD 9923)	21-02-11 (AKT 11/1052)	AKV/APC,A

Design: BRIDGES													
1	**BXXX**	PRELIMINARY DESIGN OF **BRIDGE BXXX (r. THOXXX) -**	3TT	FIL KPX CON P 99260	A-		21-05-09 (AWX 09/0028)	25-05-09 (BRD 1409)					S/S
	» »	» » » »	» »	» » » »	B-		29-05-09 (AWX 09/0036)	-	01-06-09 (AKT 09/0721)	22-06-09	ON HOLD		AKV
	» »	» » » »	» »	» » » »	DRAFT	16-09-09 mail TTA							
	» »	» » » »	» »	FIL KP3 CON P 99260	C-		09-10-09 (AWX09/0090)	20-10-09 (BRD 3240)	20-10-09 (AKT 09/1839)	10-11-09	12-11-09 (BRD 3241)		S/S/OTH
	» »	» » » »	» »	» » » »	D-		03-12-09 (AWX 09/0113)	-	30-12-09 (AKT 09/2645)	20-01-10	29-01-10 (BRD 4314)	17-02-10 (AKT 10/0450)	AKV/APC,APP
2	**BXXX**	PRELIMINARY DESIGN OF **BXXX (ROXXX)**	3TT	FIL KP3 CON P 99245	A-		31-07-09 (AWX 09/0064)	-	05-08-09 (AKT 09/1178)	26-08-09	19-10-09 (BRD 2299)	22-10-09 (AKT 09/1863)	AKV/OTH
3	**BXXX**	PRELIMINARY DESIGN OF **BRIDGE B2XXX (r. KraXXX)**	3TT	FIL KP3 CON P 99265	A-		08-10-09 (AWX 09/0088)	-	15-10-09 (AKT 09/1783)	05-11-09	06-11-09 (BRD 3180)	12-11-09 (AKT 09/2091)	AKV/OTH
4	**BXXX**	PRELIMINARY DESIGN OF **BRIDGE BXXX (r. KrXXX, LL)** (G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99253	A-		30-03-10 (AWX 10/0039)	31-03-10 (BRD 5966)	13-04-10 (AKT 10/1098)	04-05-10	14-07-10 (BRD 5967)	03-08-10 (AKT 10/3084)	AKV/APC
5	**BXXX**	PRELIMINARY DESIGN OF **BRIDGE BXXX (r. KrXXX, LL)** (G.U. 23, CH: 0+250,994 KM)(G.U. XX, CH: XXXKM)	3TT	FIL KP3 CON P 99254	A-		30-03-10 (AWX 10/0040)	31-03-10 (BRD 5963)	13-04-10 (AKT 10/1097)	04-05-10	14-07-10 (BRD 5964)	03-08-10 (AKT 10/3082)	AKV/APC
6	**BXXX**	PRELIMINARY DESIGN OF **BRIDGE BXXX (r. KrXXX, RL)**	3TT		DRAFT	10-05-10 mail TTA							
	» »	» » » »	» »		DRAFT	03-06-10 mail TTA							
	» »	» » » »	» »	FIL KP3 CON P 99252	A-		25-06-10 (AWX 10/0091)	01-07-10 (BRD 7466)	01-07-10 (AKT 10/2487)	22-07-10	13-07-10 (BRD 7464)	03-08-10 (AKT 10/3085)	AKV/APP

APPENDIX 5: SUBMISSION DESIGN FOLLOW- UP

Project: "Design, Construction, Financing, Operation, Maintenance and Exploitation of Motorway"

AWX 'S SUBMISSION FOLLOW UP - STRUCTURES' FINAL DESIGN

A/A	STR	DOCUMENT				SENT TO AWX	SENT TO CJV		SENT TO IEN				
		TITLE	ORIG	FIL	REV	(draft)	TRANS	COMMENTS	TRANS	PLANNED RETURN	RETURN IEN Prot. Nb	HARD COPY	STATUS
Design:	**UNDERPASSES**												
1	KXXX	FINAL DESIGN OF **UNDERPASS KXXX (G.U. XX XXXKM)**	3TT	FIL KP3 CON F 99267	A-		30-09-09 (AWX 09/0082)	-	05-10-09 (AKT 09/1676)	26-10-09	29-10-09 (BRD 3057)	30-10-09 (AKT 09/1963)	AKV/OTH
	» »	» » » »	» »	» » » »	B-		09-06-10 (AWX 10/0079)	14-06-10 (BRD 7222)	17-06-10 (AKT 10/2279)	08-07-10	04-08-10 (BRD 7221)	24-08-10 (AKT 10/3434)	**IFC**/APP
	» »	» » » » draft study of Underpass	SOT	» » » »	DRAFT	02-07-10 mail SOT							
	» »	» » » »	» »	» » » »	B-		22-03-11 (AWX 11/0056)		30-03-11 (AKT 11/1821)	FOR INFO			TIN
2	KXXX	FINAL DESIGN OF UNDERPASS KXXX (G.U. XX XXXKM)	3TT	FIL KP3 CON F 99246	A-		03-11-09 (AWX 09/0099)		06-11-09 (AKT 09/2027)	27-11-09	23-11-09 (BRD 3450)	25-11-09 (AKT 09/2259)	**IFC**/OTH
	» »	» » » » RETURNED TO TTA FOR CORRECTIONS NOT SUBMITTED, SOLVED WITH TIN	» »	» » » »	B-								
	» »	» » » »	» »	» » » »	» »		02-12-09 (AWX 09/0112) 19-03-10 (AWX 10/0034)	-	28-12-09 (AKT 09/2606) 29-03-10 (AKT 10/0954)	FOR INFO			TIN
	» »	» » » »	» »	» » » »	» »		30-03-10 (AWX 10/0041)	-	06-04-10 (AKT 10/1018)	FOR INFO			TIN
3	KXXX	FINAL DESIGN OF **UNDERPASS KKXXX (G.U. XX XXXKM)**	3TT	FIL KP3 CON F 99243	DRAFT	17-05-10 (mail TTA)							
	» »	» » » »	» »	» » » »	DRAFT	19-05-10 (mail TTA)			20-05-10 DRAFT CD				
	» »	» » » »	» »	» » » »	DRAFT	21-05-10 (mail TTA)			25-05-10 DRAFT CD				
	» »	» » » »	» »	» » » »	A-		08-06-10 (AWX 10/0080)	14-06-10 (BRD 7236)	17-06-10 (AKT 10/2289)	08-07-10	04-08-10 (BRD 7243)	24-08-10 (AKT 10/3430)	S/S/APC,APP
	» »	» » » »	» »	» » » »	» »		28-09-10 (AWX 10/0153)	-	30-09-10 (AKT 10/4241)	10-10-10	08-11-10 (RTC 7243)		RTC ACCEPTED
	» »	» » » »	» »	» » » »	B-		28-09-10 (AWX 10/0156)	30-09-10 (BRD 8614) APC	30-09-10 (AKT 10/4236)	21-10-10	08-11-10 (BRD 8613)	17-11-10 (AKT 10/5196)	**IFC**/APP
	» »	» » » »	» »	» » » »	» »		23-11-10 (AWX 10/0196)	-	25-11-10 (AKT 10/5342)	FOR INFO			TIN
	» »	» » » »	» »	» » » »	» »		22-03-11 (AWX 11/0053)		30-03-11 (AKT 11/1821)	FOR INFO			TIN
4	KXXX	FINAL DESIGN OF **UNDERPASS KXXX (G.U. XX XXXKM)**	3TT	FIL KP3 CON K242 3TT F 99242	A-		26-05-10 (AWX 10/0069)	28-05-10 (BRD 7005)	02-06-10 (AKT 10/1988)	23-06-10	09-07-10 (BRD 7004)	28-07-10 (AKT 10/2965)	S/S/APC,APP
	» »	» » » »	» »	» » » »	B-		28-09-10 (AWX 10/0152)	29-09-10 (BRD 8609)	30-09-10 (AKT 10/4234)	21-10-10	06-10-10 (BRD 8610)	20-10-10 (AKT 10/4598)	S/S/APC,APP
	» »	» » » »	» »	» » » »	C-		27-10-10 (AWX 10/0177)	04-11-10 (BRD 9230)	08-11-10 (AKT 10/4977)	29-11-10	15-11-10 (BRD 9229)	29-11-10 (AKT 10/5412)	**IFC**/APP
	» »	» » » »	» »	» » » »	» »		27-10-10 (AWX 10/0178)	-	04-11-10 (AKT 10/4878)	FOR INFO			TIN
	» »	» » » »	» »	» » » »	» »		23-11-10 (AWX 10/0195)	-	25-11-10 (AKT 10/5342)	FOR INFO			TIN
	» »	» » » »	» »	» » » »	» »		22-03-11 (AWX 11/0052)		30-03-11 (AKT 11/1821)	FOR INFO			TIN

5	**KXXX**	FINAL DESIGN OF **UNDERPASS KXXX (G.U. XX XXXKM)**	3TT	FIL KP3 CON F 99244	A-		16-07-10 (AWX 10/0101)	06-08-10 (BRD 8096)	11-08-10 (AKT 10/3221)	03-09-10	30-09-10 (BRD 8095)	20-10-10 (AKT 10/4597)	**IFC**/APC,APP
	» »	» » » » TIN AW3 G 89011 A-	» »	» » » »	» »		16-02-11 (AWX 11/0026)	-	21-02-11 (AKT 11/0996)	FOR INFO			TIN
6	**KXXX**	FINAL DESIGN OF **UNDERPASS KXXX (G.U. XX XXXKM)**	3TT		DRAFT	24-06-10 mail TTA							
	» »	» » » »	» »	FIL KP3 CON F 99261	A-		20-07-10 (AWX 10/0103)	28-07-10 (BRD 7866)	28-07-10 (AKT 10/2964)	18-08-10	06-09-10 (BRD 7865)	08-09-10 (AKT 10/3845)	**IFC**/APC,APP
	» »	» » » »	» »	» » » »	» »		23-11-10 (AWX 10/0193)	-	25-11-10 (AKT 10/5342)	FOR INFO			TIN
	» »	» » » »	» »	» » » »	» »		23-12-10 (AWX 10/0231)	-	28-12-10 (AKT 10/5895)	07-01-11	15-02-11 (RTC 7865)		RTC ACCEPTED
	» »	» » » »	» »	» » » »	» »		12-01-11 (AWX 11/0002)	-	20-01-11 (AKT 11/0330)	FOR INFO			TIN
7	**KXXX**	FINAL DESIGN OF **UNDERPASS KXXX (G.U. XX XXXKM)**	3TT	FIL KP3 CON F 99262	A-		20-07-10 (AWX 10/0105)	27-07-10 (BRD 7851)	27-07-10 (AKT 10/2935)	17-08-10	27-08-10 (BRD 7835)	01-09-10 (AKT 10/3643)	**IFC**/APP
	» »	» » » »	» »	» » » »	» »		23-11-10 (AWX 10/0194)	-	25-11-10 (AKT 10/5342)	FOR INFO			TIN
	» »	» » » »	» »	» » » »	» »		22-03-11 (AWX 11/0054)		30-03-11 (AKT 11/1821)	FOR INFO			TIN
8	**KXXX**	FINAL DESIGN OF **UNDERPASS KXXX (G.U. XX XXXKM)**	3TT	FIL KP3 CON F 99263	A-		21-07-10 (AWX 10/0106)	28-07-10 (BRD 7863)	28-07-10 (AKT 10/2962)	18-08-10	06-09-10 (BRD 7864)	08-09-10 (AKT 10/3848)	AKV/APC,APP
	» »	» » » »	» »	» » » »	» »		08-02-11 (AWX 11/0012)	-	14-02-11 (AKT 11/0860)	24-02-11			RTC
9	**KXXX**	FINAL DESIGN OF **UNDERPASS KXXX (G.U. XX XXXKM)**	3TT	FIL KP3 CON F 99250	A-		06-08-10 (AWX 10/0129)	17-08-10 (BRD 8253)	23-08-10 (AKT 10/3403)	13-09-10	03-09-10 (BRD 8252)	08-09-10 (AKT 10/3846)	S/S/NAP,APC
	» »	» » » »	» »	» » » »	» »		08-02-11 (AWX 11/0015)	-	14-02-11 (AKT 11/0849)	24-02-11			RTC
	» »	» » » »	» »	» » » »	B-		08-02-11 (AWX 11/0016)	14-02-11 (BRD 10513)	14-02-11 (AKT 11/0851)	07-03-11			AKV
10	**KXXX**	FINAL DESIGN OF **UNDERPASS KXXX (G.U. XX XXXKM)**	3TT	FIL KP3 CON F 99264	A-		19-10-10 (AWX 10/0170)	20-10-10 (BRD 8936)	22-10-10 (AKT 10/4636)	12-11-10	09-12-10 (BRD 8935)	20-12-10 (AKT 10/5843)	**IFC**/APC,APP
	» »	» » » »	» »	» » » »	» »		03-03-11 (AW3 11/0034)	-	10-03-11 (AKT 11/1539)	FOR INFO			TIN
	» »	» » » »	» »	» » » »	» »		15-03-11 (AWX 11/0048)	-	22-03-11 (AKT 11/1719)	01-04-11			RTC
	» »	» » » »	» »	» » » »	» »		22-03-11 (AWX 11/0055)		30-03-11 (AKT 11/1821)	FOR INFO			TIN
11	**KXXX**	UNDERPASS KXXX (G.U. XX XXXKM)	3TT	3TT F 99247	DRAFT	26-10-10 mail TTA			26-10-10 DRAFT CD		05-11-10 OK piles 23-11-10 OK pilecap		
	» »	» » » » **FINAL DESIGN OF UNDERPASS KXXX (G.U. XX XXXKM)**	» »	FIL KP3 CON F 99247	A-		18-11-10 (AWX 10/0189)	22-11-10 (BRD 9504)	23-11-10 (AKT 10/5283)	14-12-10	18-02-11 (BRD 9503)	28-02-11 (AKT 11/1351)	S/S/ AOC,APC,APP
	» »	» » » »	» »	» » » »	» »		14-03-11 (AWX 11/0043)	-	22-03-11 (AKT 11/1720)	01-04-11	31-03-11 (RTC 9503)		RTC ACCEPTED
	» »	» » » »	» »	» » » »	B-	11-03-11 HC&CD TTA	14-03-11 (AWX 11/0042)	18-03-11 (BRD 11003)	22-03-11 (AKT 11/1721)	12-04-11	31-03-11 (BRD 11004)		AKV/APC,APP
12	**KXXX**	FINAL DESIGN OF **UNDERPASS KXXX (G.U. XX XXXKM)**	3TT	FIL KP3 CON F 99266	A-		14-12-10 (AW3 10/0217)	15-12-10 (BRD 9857)	16-12-10 (AKT 10/5789)	06-01-11	18-02-11 (BRD 9856)	28-02-11 (AKT 11/1352)	S/S/APC,APP
	» »	» » » »	» »	» » » »	» »		15-03-11 (AWX 11/0045)	-	21-03-11 (AKT 11/1698)	31-03-11	28-03-11 (RTC 9856)		RTC ACCEPTED
	» »	» » » »	» »	» » » »	B-	11-03-11 HC&CD TTA	15-03-11 (AWX 11/0046)	18-03-11 (BRD 10978)	21-03-11 (AKT 11/1699)	11-04-11	28-03-11 (BRD 10979)		AKV/APP

Design:	**BRIDGES**												
1	**BXXX**	FINAL DESIGN OF **BXXX (ROXXX)**	3TT	FIL KP3 CON F 99245	A-		07-10-09 (AWX 09/0088)		14-10-09 (AKT 09/1749)	04-11-09	11-11-09 (BRD 3150)	12-11-09 (AKT 09/2092)	AKV/APC,APP
	» »	» » » »	» »	» » » »	B-								
	» »	» » » »	» »	» » » »	B-		27-09-10 (AWX 10/0151)	28-09-10 (BRD 8703)	06-10-10 (AKT 10/4348)	27-10-10	28-12-10 (BRD 8701)	13-01-11 (AKT 11/0268)	AKV/NAP,APP
2	**BXXX**	FINAL DESIGN OF **BRIDGE BXXX (r. KraXXX)** (G.U. XX, XXX KM) UPDATED 01.03.2010 WITH MARINOS REPORT	3TT	FIL KP3 CON 99265	A-		17-02-10 (AWX 10/0023)	01-03-10 (BRD 5281)	04-03-10 (AKT 10/0672)	25-03-10	26-04-10 (BRD 5282)		S/S/OTH
	» »	» » » »	» »	» » » »	B-		19-03-10 (AWX 10/0033)	19-03-10 (BRD 5621)	22-03-10 (AKT 10/0856)	12-04-10	26-04-10 (BRD 5622)	25-05-10 (AKT 10/1793)	S/S/OTH
	» »	» » » »	» »	» » » »	C-		03-05-10 (AWX 10/0056)	06-05-10 (BRD 6719)	10-05-10 (AKT 10/1516)	31-05-10	21-05-10 (BRD 6588)	31-05-10 (AKT 10/1926)	S/S/APP
	» »	» » » »	» »	» » » »	A-, B-		16-06-10 (AWX 10/0084)	-	22-06-10 (AKT 10/2342)	02-07-10	12-07-10 (RTC 5282-5622)		RTC ACCEPTED
	» »	» » » »	» »	» » » »	D-		16-06-10 (AWX 10/0083)	17-06-10 (BRD 7303)	22-06-10 (AKT 10/2341)	13-07-10	13-07-10 (BRD 7302)	17-11-10 (AKT 10/5192)	S/S/APP
	» »	» » » »	» »	» » » »	E-		18-11-10 (AWX 10/0190)	22-11-10 (BRD 9493)	22-11-10 (AKT 10/5276)	13-12-10	13-12-10 (BRD 9491)	10-01-11 (AKT 11/0124)	AKV/APC,APP
	» »	» » » »	» »	» » » »	» »		16-12-10 (AWX 10/0223)	-	20-12-10 (AKT 10/5848)	FOR INFO			TIN
	» »	» » » »	» »	» » » »	» »						23-12-10 (BRD 9491A)		**IFC**/APP
3	**BXXX**	FINAL DESIGN OF **BRIDGE BXXX (r. THOXXX)** (G.U. XX, XXX KM)	3TT	FIL KP3 CON F 99260	A-		20-04-10 (AWX 10/0051)	26-04-10 (BRD 6398)	29-04-10 (AKT 10/1405)	20-05-10	08-06-10 (BRD 6402)	15-06-10 (AKT 10/2228)	AKV/ NAP,APC,APP
	» »	» » » »	» »	» » » »	» »	04-02-11 HC TTA	11-02-11 (AWX 11/0023)	-	16-02-11 (AKT 11/0931)	26-02-11			RTC
	» »	» » » »	» »	» » » »	B-	04-02-11 10-02-11 HC&CD TTA	11-02-11 (AWX 11/0024)	16-02-11 (BRD 10564)	17-02-11 (AKT 11/0962)	10-03-11			AKV
4	**BXXX**	FINAL DESIGN OF **BRIDGE BXXX (r. KRXXX)** (G.U. XX, XXX KM)	3TT	FIL KP3 CON F 99253	A-		02-08-10 (AWX 10/0113)	09-08-10 (BRD 8112)	11-08-10 (AKT 10/3231)	01-09-10	15-10-10 (BRD 8110)	29-10-10 (AKT 10/4759)	AKV/AOC
	» »	» » » »	» »	» » » »	» »	04-02-11 HC TTA							RTC
	» »	» » » »	» »	» » » »	B-	04-02-11 HC&CD TTA	περιμένουμε deck drainage από RACE						
5	**BXXX**	FINAL DESIGN OF **BRIDGE B2XXX (r. KRXXX)** (G.U. XX, XXX KM)	3TT	FIL KP3 CON F 99254	A-		03-08-10 (AWX 10/0114)	10-08-10 (BRD 8134)	12-08-10 (AKT 10/3245)	02-09-10	15-10-10 (BRD 8131)	29-10-10 (AKT 10/4758)	S/S/NAP,AOC
	» »	» » » »	» »	» » » »	» »	04-02-11 HC TTA	10-02-11 (AWX 11/0020)	-	16-02-11 (AKT 11/0930)	26-02-11			RTC
	» »	» » » »	» »	» » » »	B-	04-02-11 09-02-11 HC&CD TTA	10-02-11 (AWX11/0021)	16-02-11 (BRD 10571)	09-03-11 (AKT 11/1483)	30-03-11			AKV
6	**BXXX**	FINAL DESIGN OF **BRIDGE BXXX (r. KRXXX)** (G.U. XX, XXX KM)	3TT	FIL KP3 CON F 99252	A-		13-12-10 (AWX 10/0216)	15-12-10 (BRD 9875)	16-12-10 (AKT 10/5801)	06-01-11			AKV

APPENDIX 6: Designs-DCPTIS Rev B CONNECTION WITH PRIMAVERA

CONNECTION WITH PRIMAVERA SOFTWARE

A/A	Activity ID	Code	Activity Name	start_date	end_date
	J122020310	EKXXTB.D.04B.22N.2.B02.0100	Pavement asphalt - Stage 2, Final Design GU XXN	15/4/2009 8:00:00 πμ	8/9/2009 5:00:00 μμ
	J122020320	EKXXTB.D.04B.22N.2.B02.0100	Pavement asphalt - Stage 2, Final Design GU XXN approval		29/9/2009 5:00:00 μμ
	J122020250	EKXXTB.D.04B.22N.2.B02.0200	Box culvert > 3x3 - Final design XXXXXX	12/6/2009 8:00:00 πμ	23/7/2009 5:00:00 μμ
	J122020260	EKXXTB.D.04B.22N.2.B02.0200	Box culvert > 3x3 - Final design XXXXXX approval		13/8/2009 5:00:00 μμ
	J122020420	EKXXTB.D.04B.22N.2.B02.0400	Underpasses - Preliminary Design XXXXXX	7/7/2009 8:00:00 πμ	29/9/2009 5:00:00 μμ
	J122020430	EKXXTB.D.04B.22N.2.B02.0400	Underpasses - Final Design XXXXXX	21/10/2009 8:00:00 πμ	2/12/2009 5:00:00 μμ
	J122020440	EKXXTB.D.04B.22N.2.B02.0400	Underpasses - Preliminary Design XXXXXX approval		20/10/2009 5:00:00 μμ
	J122020450	EKXXTB.D.04B.22N.2.B02.0400	Underpasses - Final Design XXXXXX approval		23/12/2009 5:00:00 μμ
	J122020460	EKXXTB.D.04B.22N.2.B02.0500	ROXXX - Bridge - Preliminary Design	7/7/2009 8:00:00 πμ	29/9/2009 5:00:00 μμ
	J122020465	EKXXTB.D.04B.22N.2.B02.0500	ROXXX - Bridge - Final Design	21/10/2009 8:00:00 πμ	2/12/2009 5:00:00 μμ
	J122020470	EKXXTB.D.04B.22N.2.B02.0500	ROXXX - Bridge - Preliminary Design approval		20/10/2009 5:00:00 μμ
	J122020480	EKXXTB.D.04B.22N.2.B02.0500	ROXXX - Bridge - Final Design approval		23/12/2009 5:00:00 μμ
	J123020311	EKXXTB.D.04B.23N.2.B02.0100	Pavement asphalt -Stage 2, Final Design GUXX	15/4/2009 8:00:00 πμ	8/9/2009 5:00:00 μμ
	J123020321	EKXXTB.D.04B.23N.2.B02.0100	Pavement asphalt -Stage 2, Final Design GUXX approval		29/9/2009 5:00:00 μμ
	J123020390	EKXXTB.D.04B.23N.2.B02.0300	Ret. Walls in Fill - Final Design RW2XXXXXX	9/11/2009 8:01:00 πμ	30/3/2010 8:01:00 πμ
	J123020400	EKXXTB.D.04B.23N.2.B02.0300	Ret. Walls in Fill - Final Design RW2XXXXXX approval		22/4/2010 8:01:00 πμ
	J123020421	EKXXTB.D.04B.23N.2.B02.0400	Underpasses - Preliminary Design XXXXXX	7/5/2009 8:00:00 πμ	9/7/2009 5:00:00 μμ
	J123020422	EKXXTB.D.04B.23N.2.B02.0400	Underpasses - Preliminary Design XXXXXX	9/3/2009 8:00:00 πμ	4/6/2009 5:00:00 μμ
	J123020471	EKXXTB.D.04B.23N.2.B02.0400	Underpasses - Final Design XXXXXX approval		31/8/2009 5:00:00 μμ
	J123020470	EKXXTB.D.04B.23N.2.B02.0500	KRXXX - new bridge - Preliminary Design	9/3/2009 8:00:00 πμ	4/6/2009 5:00:00 μμ
	J123020472	EKXXTB.D.04B.23N.2.B02.0500	KRXXX - new bridges - Final Design	29/6/2009 8:00:00 πμ	7/8/2009 5:00:00 μμ
	J123020473	EKXXTB.D.04B.23N.2.B02.0500	KRXXX - existing bridge - Preliminary Design	21/9/2009 8:00:00 πμ	14/12/2009 5:00:00 μμ
	J123020474	EKXXTB.D.04B.23N.2.B02.0500	KRXXX - existing bridge - Final Design	8/1/2010 8:00:00 πμ	19/2/2010 5:00:00 μμ
	J123020490	EKXXTB.D.04B.23N.2.B02.0500	KRXXX - new bridge - Preliminary Design approval		26/6/2009 5:00:00 μμ
	J123020500	EKXXTB.D.04B.23N.2.B02.0500	KRXXX - new bridges - Final Design approval		31/8/2009 5:00:00 μμ
	J123020510	EKXXTB.D.04B.23N.2.B02.0500	KRXXX - existing bridge - Preliminary Design approval		7/1/2010 5:00:00 μμ
	J123020520	EKXXTB.D.04B.23N.2.B02.0500	KRXXX - existing bridge - Final Design approval		12/3/2010 5:00:00 μμ
	J125020490	EKXXTB.D.04B.25N.2.B02.0500	KRAXXX- Bridges - Preliminary Design	18/11/2009 8:00:00 πμ	11/2/2010 5:00:00 μμ
	J125020495	EKXXTB.D.04B.25N.2.B02.0500	KRAXXX- Bridge - Final Design	8/3/2010 8:00:00 πμ	21/4/2010 5:00:00 μμ
	J125020500	EKXXTB.D.04B.25N.2.B02.0500	KRAXXX - Bridges - Preliminary Design approval		5/3/2010 5:00:00 μμ
	J125020510	EKXXTB.D.04B.25N.2.B02.0500	KRAXXX - Bridge - Final Design approval		13/5/2010 5:00:00 μμ
	C4GE021527	EKXXTB.D.04B.GEN.2.B02.0450	Tunnel(XXX)Road Design "Locked"		5/2/2009 5:00:00 μμ
	C4GE022412	EKXXTB.D.04B.GEN.2.B02.0450	Tun(XXX)decision about lanes number in Tunnel	1/12/2008 8:00:00 πμ	
	C4GE022415	EKXXTB.D.04B.GEN.2.B02.0450	Tunnel (XXX) Portals Final Design (Temporary Support)	29/12/2008 8:01:00 πμ	23/2/2009 8:01:00 πμ
	C4GE022425	EKXXTB.D.04B.GEN.2.B02.0450	Tunnel (XXX) Portals Final Design IE approval		10/3/2009 8:01:00 πμ
	C4GE022485	EKXXTB.D.04B.GEN.2.B02.0450	Tunnel(XXX)TRAS Audit	5/3/2009 8:01:00 πμ	27/3/2009 8:01:00 πμ
	C4GE022495	EKXXTB.D.04B.GEN.2.B02.0450	Tunnel (XXX) Excavation and Temporary Support Final Design IE Approval		29/6/2009 8:01:00 πμ
	C4GE021610	EKXXTB.D.04B.GEN.2.B02.0750	E/M Tunnel (XXX)prel des preparation & submission	14/1/2009 8:01:00 πμ	5/3/2009 8:01:00 πμ
	C4GE021620	EKXXTB.D.04B.GEN.2.B02.0750	E/M Tunnel (XXX)prel des approval		27/3/2009 8:01:00 πμ
	C4GE021630	EKXXTB.D.04B.GEN.2.B02.0750	E/MTun(XXX)Final des prep&subm - S/S & Cont	27/3/2009 8:01:00 πμ	16/6/2009 8:01:00 πμ
	C4GE021635	EKXXTB.D.04B.GEN.2.B02.0750	E/MTun(XXX)Final des prep&subm - E/M Inst	16/6/2009 8:01:00 πμ	10/12/2009 8:01:00 πμ
	C4GE021640	EKXXTB.D.04B.GEN.2.B02.0750	E/M Tunnels(XXX)Final des approval		4/1/2010 8:01:00 πμ
	C4GE021650	EKXXTB.D.04B.GEN.2.B02.0750	E/M Tunnels(XXX)prel des preparation & submission	4/12/2008 8:01:00 πμ	28/1/2009 8:01:00 πμ
	C4GE021660	EKXXTB.D.04B.GEN.2.B02.0750	E/M for Tunnels(XXX)prel des approval		18/2/2009 8:01:00 πμ
	C4GE021670	EKXXTB.D.04B.GEN.2.B02.0750	E/M TunnelsXXX)Final des preparation & submission	18/2/2009 8:01:00 πμ	11/6/2009 8:01:00 πμ
	C4GE021680	EKXXTB.D.04B.GEN.2.B02.0750	E/M for Tunnels (XXX) Final des approval		2/7/2009 8:01:00 πμ

APPENDIX 7: LIST OF ITEMS-STRUCTURES

LIST OF ITEMS-STRUCTURES		
ID Code	Items Description-units	comments
0001	Concrete (m^3) C 20-25	
0002	Concrete (m^3) C 16-20	
0003	Concrete (m^3) C 12-15	
0004	Concrete (m^3) C 8-10	
0005	Concrete (m^3) C30/37	
0011	Reinforcement (kg)	
0012	Asphalt Coating (m^2)	
0013	Membrane Sealing (m^2)	
0014	Quarry Stones (m^3)	
0015	Geotextile (m^2)	
0016	Concrete Drainage Pipe Φ200 (m)	
0017	Rubble Work (m^3)	
0018	Concrete Pipe Σ75 (m)	
0019	Transional Backfill (m^3)	
0020	Excavation material (m^3)	
0021	Prefab beams (pieces)	
0022	Bituminus Coating (m^2)	
0023	Drainage Pipe (m)	
0024	Expansion construction Joints T330 (m)	
0025	Pot bearings 600x650(mm), tel=330mm (pieces)	
0026	Pot bearings 600x650(mm), tel=154mm (pieces)	
0027	ot bearings 600x650(mm), tel=132mm (pieces)	
0028	Steel barriers ΣΤΕ 1 (m)	
0029	Flexcell type Joint Material	
0030	Other Materials	
0031	Expansion Joint Ceiling Material (plasticjoint material)	
0040	Gunite (m^3)	
0042	Reinforcement L.G (Kg)	
0047	Reinforcement T188 (Tn)	
0049	ANCHORS 4M (TMX)	
0050	ANCHORS SELF DRILLING	
0055	Cement (Tn)	
9001	Concrete (m^3) C 8-10 - (m^3)	

9002	Walls - έως 6,50m - (m^3)	
9003	Walls - από 6,51m έως 10,00m - (m^3)	
9004	Pilecaps (m^3)	
9005	Foundation Concrete- slabs (m^3)	
9006	Concrete culverts (m^3)	
9007	Piles Reinforcement (Kg)	
9009	Retaining Walls 6,00m ύψος) (m^3)	
9010	Retaining Walls - από 6,00m έως 10,00m - ύψος) (m^3)	
9011	Abutments έως 6,00m ύψος (m^3)	
9012	Abutments 6,00m έως 10,00m ύψος (m^3)	
9013	Abutments 10,00m έως 15,00m ύψος (m^3)	
9014	Underpasses, Walls and Slabs έως 6,00m ύψος (m^3)	
9015	Side pavements (m^3)	
9032	Pile Construction Φ600 (m)	
9035	Pile Construction Φ800 (m)	
9038	Pile Construction Φ1000 (m)	
9041	Pile Construction Φ1200 (m)	
9044	Pile Construction Φ1500 (m)	
9900	Additional working rates Technician (HM)	
9901	Additional working rates Assistant Technician (HM)	
9902	Additional working rates Worker (HM)	

APPENDIX 8: Machineries

PLANT ID	PLANT DESCRIPTION	PLANT TYPE ID	ID CODE	PLANT STATUS	PLANT LOCATION ID	PLANT LOCATION	MANUFACTURER ID	MANUFACTURER	COMPANY OWNERSHIP ID	COMPANY OWNERSHIP
1036156	WHEEL LOADER - CAT 966G	14	1076167	Active	E	EAST			10	company 10
1036162	WHEEL LOADER - CAT 966G	14	1076153	Active	W	WEST			10	company 10
1036187	WHEEL LOADER - CAT 966H	14	1076168	Active	E	EAST			10	company 10
1076134	EXCAVATOR TRUCK (HAMMER) - LIEBHERR R912T	14	1076212	Active	W	WEST			10	company 10
1076138	EXCAVATOR TRUCK (HAMMER - LIEBHERR R912T	14	1076113	Active	W	WEST			10	company 10
1076153	EXCAVATOR TRUCK (HAMMER) - CAT 328D	14	1076225	Active	E	EAST			10	company 10
1076167	WHEEL EXCAVATOR - CAT 328D	14	1076224	Active	W	WEST			10	company 10
1076168	WHEEL EXCAVATOR- CAT 328D	14	1076255	Active	E	EAST			10	company 10
1166112	JUMBO AXERA - DT 820	14	3506117	Active	W	WEST			10	company 10
3506109	JUMBO GUNITE- CIFA	14	3506167	Active	W	WEST			10	company 10
3506118	JUMBO GUNITE - NORMET	14	3506169	Active	E	EAST			10	company 10
3506118	TRUCK MERCEDES 3535K	14	2026169	Active	E	EAST			10	company 10
3506118	TRUCK MERCEDES 3535K	14	2036155	Active	E	WEST			10	company 10
3506118	TRUCK MERCEDES 3538K	14	2225158	Active	E	WEST			10	company 10
3506118	ΜΠΕΤΟΝΙΕΡΑ ASTRA HD6 84.38Z	14	2036155	Active	E	EAST			10	company 10
3506118	ΜΠΕΤΟΝΙΕΡΑ MERCEDES 3028	14	2036157	Active	E	EAST			10	company 10
3506118	TRUCK ACTROS 4140K	14	2045144	Active	E	EAST			10	company 10
3506118	TRUCK ACTROS 4140K	14	2045166	Active	E	EAST			10	company 10

APPENDIX 9: BUDGET Bridge

		BUDGET BRIDGE TOTAL 00+000						
		AWXX.0XX.XXN.XXX.1.07						
		1. Demolition of Existing Structure	2. Excavation, Piles and Pilecap	3. Abutments and Piers	4.Deck Slab & Approach Slab	5.Finishing Works (Deck Slab)	UNIT COST	COST
Materials	A5							
Concrete (m³)								
C 8-10			279,77				43,46	12.158,80
C 20-25			1.536,58		67,56	326,85	63,44	122.502,01
C 30-37			1.616,26	5.862,07	1.192,78		63,63	551.742,73
								0,00
Reinforcing Steel B500C (Kg)			278.954,94	307.948,99	176.735,76	24.242,20	0,75	590.911,42
Prefab beams (pieces)				35,00			26.000,00	910.000,00
Bituminus Coating (m²)				3147,28				0,00
Membrane Sealing (m²)				4697,00				0,00
Drainage Pipe (m)					2490,80			0,00
Transional Backfill (kg)								0,00
Flexcell type Joint Material								0,00
Excavation Material (m³)								0,00
Expansion Joint Cealing Material (plasticjoint material)								0,00
Expansion construction Joints T330 (m)				52,00				
Pot bearings 600x650(mm), tel=330mm (pieces)				20,00				
Pot bearings 600x650(mm), tel=154mm (pieces)				40,00				
Pot bearings 600x650(mm), tel=132mm (pieces)				60,00				
Steel barriers ΣTE 1 (m)					796,20			
								0,00
Total								**2.187.314,96**

APPENDIX 10: ACWP Bridge

		ACTUAL COST DRAFT TABLE BRIDGE EXAMPLE RL 00+000							
		AWXX.XXX.XXX.XXX.1.07							
		1. Demolition of Existing Structure	2. Excavation, Piles and Pilecap	3. Abutments and Piers	4.Deck Slab	5.Finishing Works (Deck Slab)	6.Retaining Walls and Approach Embankments	UNIT COST	COST
		AW3.04B.25N.B11.1.07.01	AW3.04B.25N.B11.1.07.02	AW3.04B.25N.B11.1.07.03	AW3.04B.25N.B11.1.07.04	AW3.04B.25N.B11.1.07.05	AW3.04B.25N.B11.1.07.06		
Plant	A4	0	0	0	0	0	0		0,00
Materials	A5								
Concrete (m³)									
C 8-10		0	0	0	0	0	0		0,00
C 12/15									
C 20-25		0	0	0	0	0	0		0,00
C 30-37		0	0	0	0	0	0		0,00
Gunite		0	0	0	0	0	0		0,00
Reinforcing Steel B500C (Kg)		0	0	0	0	0	0		0,00
Bituminus Coating (m²)		0	0	0	0	0	0		0,00
Membrane Sealing (m²)		0	0	0	0	0	0		0,00
Drainage Pipe (m)		0	0	0	0	0	0		0,00
Flexcell type Joint Material		0	0	0	0	0	0		0,00
Excavation Material (m³)		0	0	0	0	0	0		0,00
Expansion Joint Cealing Material (plasticjoint material)		0	0	0	0	0	0		0,00
Subcontractors	A6	0	0	0	0	0	0		0,00
Overhead Expences	A7	0	0	0	0	0	0		0,00
Total Cost 01-07/ 02/2010									**0,00**

APPENDIX 11: EMPLOYEES EXTRACTION FILE

Employee Code	Employee FullName	2010-8-26	Work Hours	2010-8-27	Work Hours	2010-8-28	Work Hours	2010-8-29	Work Hours	2010-8-30	Work Hours	2010-8-31	Cost Code	Cost Description
0001	ΓΚΟΛΦΙΝΟΠΟΥΛΟΣ ΙΩΑΝ.	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02	8		0	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02	AW3.04B.25N.B11.01.07.06	Retaining Walls and Approach Embankments
0002	ΝΤΑΒΕΛΗΣ ΠΑΝΑΓΙΩΤΗΣ	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02	8		0	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02	AW3.04B.25N.B11.01.07.05	Finishing Works (Deck Slab)
0003	ΠΡΕΖΑΣ ΣΤΑΥΡΟΣ	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02	8	AW3.04B.25N.B11.01.08.02	8	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02	AW3.04B.25N.B11.01.07.04	Deck Slab
0004	ΤΣΟΚΑΝΑΣ ΑΡΙΣΤ.		0		0		0		0		0		AW3.04B.25N.B11.01.07.03	Abutments and Piers
0005	ΛΑΛΙΩΤΗΣ ΔΗΜΗΤΡΙΟΣ		0		0		0		0		0		AW3.04B.25N.B11.01.07.02	Excavation Piles and Pilecap
0006	ΚΟΛΟΜΟΔΗΣ ΓΕΩΡΓΙΟΣ		0		0		0		0		0		AW3.04B.25N.B11.01.07.01	Demolition of Existing Structure
0007	ΝΙΚΟΛΟΠΟΥΛΟΣ ΤΑΞΙΑΡΧΗΣ		0		0		0		0		0		AW3.04B.25N.B11.01.07	BXXX 00+000 KRXXX-RL
0008	ΒΛΑΧΟΓΙΑΝΝΗΣ ΒΑΣΙΛΕΙΟΣ		0		0		0	AW3.04B.25N.B11.01.07.02	8		0			
0009	ΓΕΩΡΓΙΟΥ ΕΥΣΤΑΘΙΟΣ		0		0	AW3.04B.25N.B11.01.07.02	8	AW3.04B.25N.B11.01.07.02	8	AW3.04B.25N.B11.01.07.02	8			
0010	ΓΚΟΥΜΑΣ ΣΠΥΡΙΔΩΝ		0		0		0		0		0			
0011	ΖΙΑΜΠΑΡΑΣ ΚΩΝ ΝΟΣ		0		0		0		0		0			
0012	ΗΛΙΑΣ ΓΕΩΡΓΙΟΣ	AW3.04B.25N.B11.01.07.02	13		0		0		0		0			
0013	ΜΑΚΡΟΠΟΥΛΟΣ ΖΩΗΣ	AW3.04B.25N.B11.01.07.02	10		0	AW3.04B.25N.B11.01.07.02	8	AW3.04B.25N.B11.01.07.02	8	AW3.04B.25N.B11.01.07.02	10	AW3.04B.25N.B11.01.07.02		
0014	ΚΑΝΙΟΣ ΑΘΑΝΑΣΙΟΣ		0		0		0		0		0			
0015	ΚΑΡΑΓΙΑΝΝΗΣ ΔΗΜΗΤΡΙΟΣ		0		0	AW3.04B.25N.B11.01.07.02	8	AW3.04B.25N.B11.01.07.02	8		0			
0016	ΜΙΧΑΗΛΙΔΗΣ ΚΩΝ ΝΟΣ		0		0		0		0		0			
0017	ΠΕΤΑΡΟΥΔΑΣ ΑΠΟΣΤΟΛΟΣ		0		0		0		0		0			
0018	ΚΥΡΙΤΣΗΣ ΚΩΝ ΝΟΣ		0		0		0		0		0			
0019	ΜΗΝΑΣ ΝΙΚΟΛΑΟΣ		0		0		0		0		0			
0020	ΠΑΠΑΔΙΑΜΑΝΤΟΠΟΥΛΟΣ ΙΩΝ.		0		0		0		0		0			
0021	ΤΕΜΠΕΛΗΣ ΙΩΑΝΝΗΣ		0		0		0		0		0			
0022	ΤΣΑΠΙΚΟΥΝΗΣ ΝΙΚΟΛΑΟΣ		0		0		0		0		0			
0023	ΦΩΤΟΠΟΥΛΟΣ ΙΩΑΝΝΗΣ		0		0		0		0		0			
0024	ΠΑΠΑΔΗΜΗΤΡΙΟΥ ΓΕΩΡΓ.		0		0		0		0		0			
0025	ΘΩΜΟΠΟΥΛΟΣ ΣΠΗΛΙΟΣ		0		0		0		0		0			
0026	ΚΟΥΛΟΥΡΗΣ ΚΩΝ/ΝΟΣ		0		0		0		0		0			
0027	ΜΕΡΤΙΚΑΣ ΑΝΑΣΤΑΣΙΟΣ		0		0		0		0		0			
0028	ΠΑΓΚΕΙΟΣ ΣΠΥΡΟΣ		0		0		0		0		0			
0029	ΜΗΤΣΟΚΑΛΗΣ ΣΩΤΗΡΙΟΣ		0		0		0		0		0			
0030	ΓΙΑΝΝΟΠΟΥΛΟΣ ΣΠΥΡΟΣ		0		0		0		0		0			
0031	ΜΑΛΛΗΣ ΠΑΝΑΓΙΩΤΗΣ		0		0		0		0		0			
0114	ΓΕΩΡΓΟΥΛΗΣ ΤΙΜΟΛΕΩΝ		0		0		0		0		0			
0115	ΧΑΜΑΚΙΩΤΗΣ ΓΕΩΡΓΙΟΣ		0		0		0		0		0			
0116	ΠΛΙΑΤΣΙΚΟΥΡΑΣ Π.		0		0		0		0		0			
0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ		0		0		0		0		0			
0118	ΚΡΑΜΠΑΚΟΥΚΗΣ ΠΑΝΑΓΙΩΤΗΣ		0		0		0		0		0			
0119	ΡΗΓΑΣ ΘΕΟΦΑΝΗΣ		0		0		0		0		0			
0120	ΛΑΤΣΙΝΟΠΟΥΛΟΣ ΜΟΔΙΣΤΟΣ		0		0		0		0		0			
0121	ΘΩΜΟΠΟΥΛΟΣ ΣΠΗΛΙΟΣ		0		0		0		0		0			
0122	ΜΠΑΣΤΟΓΙΑΝΝΗΣ ΝΙΚΟΣ		0		0		0		0		0			
0123	ΝΙΚΟΛΟΠΟΥΛΟΣ ΗΛΙΑΣ		0		0		0		0		0			
0124	ΛΥΡΑΣ ΣΠΥΡΟΣ		0		0		0		0		0			
0125	ΚΟΛΥΒΑΣ ΜΙΧΑΛΗΣ		0		0		0		0		0			
0126	ΛΙΒΑΝΑΣ ΙΩΑΝΝΗΣ		0		0		0		0		0			
0127	ΒΛΑΧΟΓΙΑΝΝΗΣ ΒΑΣΙΛΕΙΟΣ		0		0		0		0		0			
0128	ΝΙΚΟΛΟΠΟΥΛΟΣ ΤΑΞΙΑΡΧΗΣ		0		0		0	AW3.04B.25N.B11.01.07.02	8		0			

APPENDIX 12: MATERIALS EXTRACTION FILE

2010-10-30	Materials	Cost Category	Unit Price	AW3.04B.25N.B11.01.07.06 - Retaining Walls and Approach Embankments	AW3.04B.25N.B11.01.07.05 - Finishing Works Deck Slab	AW3.04B.25N.B11.01.07.04 - Deck Slab	AW3.04B.25N.B11.01.07.03 - Abutments and Piers	AW3.04B.25N.B11.01.07.02 - Excavation Piles and Pilecap	AW3.04B.25N.B11.01.07.01 - Demolition of Existing Structure
0001	Concrete (m^3) C 20-25	2	0	0	0	0	0	0	0
0002	Concrete (m^3) C 16-20	2	0						
0003	Concrete (m^3) C 12-15	2	0						
0004	Concrete (m^3) C 8-10	2	0						
0005	Concrete (m^3) C30/37	2	0				18		
0011	Reinforcement (kg)	2	0				96970	4070	
0012	Asphalt Coating (m^2)	2	0						
0013	Membrane Sealing (m^2)	2	0				18		
0014	Quary Stones (m^3)□	2	0						
0015	Geotextile (m^2)	2	0						
0016	Concrete Drainage Pipe Φ200 (m)	2	0						
0017	Rubble Work (m^3) □	2	0						
0018	Concrete Pipe Σ75 (m)	2	0						
0019	Transional Backfill (m^3)	2	0						
0020	Excavation material (m^3)	2	0						
0021	Prefab beams (pieces)	2	0						
0022	Bituminus Coating (m^2)	2	0						
0023	Drainage Pipe (m)	2	0						
0024	Expansion construction Joints T330 (m)	2	0						
0025	Pot bearings 600x650(mm), tel=330mm (pieces)	2	0						
0026	Pot bearings 600x650(mm), tel=154mm (pieces)	2	0						
0027	ot bearings 600x650(mm), tel=132mm (pieces)	2	0						
0028	Steel barriers ΣΤΕ 1 (m)	2	0						
0029	Flexcell type Joint Material	2	0						
0030	Other Materials	2	0						
0031	Expansion Joint Cealing Material (plasticjoint material)	2	0						
0040	Gunite (m^3)	2	0						
0042	Reinforcement L.G (Kg)	2	0						
0047	Reinfiorcement T188 (Tn)	2	0						
0049	ANCHORS 4M (TMX)	2	0						
0050	ANCHORS SELF DRILLING	2	0						
0055	Cement (Tn)	2	0						
0041	Concrete (m^3) C 8-10 - (m^3)	2	0						
0042	Walls - έως 6,50m - (m^3)	2	0						
0043	Walls - από 6,51m έως 10,00m - (m^3)	2	0						
0044	Pilecaps (m^3)	2	0						
0045	Foundation Concrete- slabs (m^3)	2	0						
0046	Concrete culverts (m^3)	2	0						
0047	Piles Reinforcment (Kg)	2	0						
0048	Retaining Walls 6,00m ύψος) (m^3)	2	0						
0049	Retaining Walls - από 6,00m έως 10,00m - ύψος) (m^3)	2	0						
0050	Abutments έως 6,00m ύψος (m^3)	2	0						
0052	Abutments 6,00m έως 10,00m ύψος (m^3)	2	0						
0053	Abutments 10,00m έως 15,00m ύψος (m^3)	2	0						
0054	Underpasses, Walls and Slabs έως 6,00m ύψος (m^3)	2	0						
0055	Side pavements (m^3)	2	0						
0056	Pile Construction Φ600 (m)	2	0						
0057	Pile Construction Φ800 (m)	2	0						
0058	Pile Construction Φ1000 (m)	2	0						
0059	Pile Construction Φ1200 (m)	2	0						
9001	Pile Construction Φ1500 (m)	2	0						
9002	Additional working rates Technician (HM)	2	0						
9003	Additional working rates Assistant Technician (HM)	2	0						
9004	Additional working rates Worker (HM)	2	0						

APPENDIX 13: SUBCONTRACTORS EXTRACTION FILE

SubContractors'	Works Description	Unit Price	2010-7-31	Qnt	2010-8-1	Qnt	2010-8-2	Qnt	2010-8-3	Qnt	2010-8-4	Qnt	2010-8-5	Qnt	2010-8-6	Qnt	-	Cost Code	Cost Description
9001	Concrete (m^3) C 8-10 - (m^3)	0	AW3.04B.25N.B11.01.07.03	26		0		0		0		0		0		0		AW3.04B.25N.B11.01.07.06	Retaining Walls and Approach Embankments
9002	Walls - έως 6,50m - (m^3)	0		0		0		0		0		0		0		0		AW3.04B.25N.B11.01.07.05	Finishing Works (Deck Slab)
9003	Walls - από 6,51m - 10,00m - (m^3)	0		0		0		0		0		0		0		0		AW3.04B.25N.B11.01.07.04	Deck Slab
9004	Pilecaps (m^3)	0		0		0		0		0		0		0		0		AW3.04B.25N.B11.01.07.03	Abutments and Piers
9005	Foundation Concrete- slabs (m^3)	0	AW3.04B.25N.B11.01.07.02	185,98		0		0		0		0		0		0		AW3.04B.25N.B11.01.07.02	Excavation Piles and Pilecap
9006	Concrete culverts (m^3)	0		0		0		0		0		0		0		0		AW3.04B.25N.B11.01.07.01	Demolition of Existing Structure
9007	Piles Reinforcment (Kg)	0	AW3.04B.25N.B11.01.07.02	32327		0		0		0		0		0		0		AW3.04B.25N.B11.01.07	BXXX 00+000 KRXXX-RL
9009	Retaining Walls 6,00m (m^3)	0	AW3.04B.25N.B11.01.07.03	132797		0		0		0		0		0		0			
9010	Retaining Walls - 6,00m - 10,00m - ύψος) (m^3)	0		0		0		0		0		0		0		0			
9011	Abutments έως 6,00m ύψος (m^3)	0		0		0		0		0		0		0		0			
9012	Abutments 6,00m - 10,00m - (m^3)	0	AW3.04B.25N.B11.01.07.02	26,89		0		0		0		0		0		0			
9013	Abutments 10,00m - 15,00m - (m^3)	0		0		0		0		0		0		0		0			
9014	Underpasses, Walls and Slabs -6,00m - (m^3)	0	AW3.04B.25N.B11.01.07.02	160		0		0		0		0		0		0			
9015	Side pavements (m^3)	0		0		0		0		0		0		0		0			
9032	Pile Construction Φ600 (m)	0		0		0		0		0		0		0		0			
9035	Pile Construction Φ800 (m)	0		0		0		0		0		0		0		0			
9038	Pile Construction Φ1000 (m)	0		0		0		0		0		0		0		0			
9041	Pile Construction Φ1200 (m)	0		0		0		0		0		0		0		0			
9044	Pile Construction Φ1500 (m)	0		0		0		0		0		0		0		0			
9900	Additional working rates Technician (HM)	0		0		0		0		0		0		0		0			
9901	Additional working rates Assistant Technician (HM)	0		0		0		0		0		0		0		0			

APPENDIX 14: Bridge, Plant data: Model extraction report

Κόστος

4/5/2012

Κ.Κοστους	Ειδος	Περιγραφη		Ποσοτητα Πραγματ.	Τιμη Μον.	Συνολικη Αξια
07/02/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	8.00	77.00	616.00
09/02/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
10/02/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
23/02/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
25/02/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	10.00	49.00	490.00
25/02/2010	018	MAN-PM31024 25.372 FNLW	AW3.04B.25N.B11.01.07.01	10.00	32.92	329.20
26/02/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
01/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	11.00	49.00	539.00
02/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	10.00	49.00	490.00
03/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	10.00	49.00	490.00
04/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	10.00	49.00	490.00
05/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	10.00	49.00	490.00
06/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	8.00	49.00	392.00
07/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	8.00	49.00	392.00
08/03/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
09/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	10.00	49.00	490.00
09/03/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
10/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	10.00	49.00	490.00
10/03/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
12/03/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
15/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	12.00	49.00	588.00
15/03/2010	018	MAN-PM31024 25.372 FNLW	AW3.04B.25N.B11.01.07.01	10.00	32.92	329.20
16/03/2010	008	CATERPILLAR M320, KOMATSU	AW3.04B.25N.B11.01.07.01	10.00	39.50	395.00
16/03/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
16/03/2010	018	MAN-PM31024 25.372 FNLW	AW3.04B.25N.B11.01.07.01	10.00	32.92	329.20
17/03/2010	008	CATERPILLAR M320, KOMATSU	AW3.04B.25N.B11.01.07.01	10.00	39.50	395.00
17/03/2010	009	HYUNDAI ROBEX 450LC-7, LIEB	AW3.04B.25N.B11.01.07.01	10.00	77.00	770.00
17/03/2010	015	MAN με αντλία PUTZMEISTER, 2	AW3.04B.25N.B11.01.07.01	13.00	73.85	960.05
18/03/2010	007	CATERPILLAR D8R,BOMAC BW	AW3.04B.25N.B11.01.07.01	10.00	49.00	490.00

1

APPENDIX 15: Bridge, Personnel data: Model extraction report

Κόστος

4/5/2012

Κ.Κοστους	Είδος	Περιγραφη		Ποσοτητα Πραγματ.	Τιμη Μον.	Συνολική Αξία
07/02/2010	0010	ΓΚΟΥΜΑΣ ΣΠΥΡΙΔΩΝ	AW3.04B.25N.B11.01.07.01	8.00	11.45	91.56
09/02/2010	0009	ΓΕΩΡΓΙΟΥ ΕΥΣΤΑΘΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	12.32	123.20
10/02/2010	0009	ΓΕΩΡΓΙΟΥ ΕΥΣΤΑΘΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	12.32	123.20
23/02/2010	0009	ΓΕΩΡΓΙΟΥ ΕΥΣΤΑΘΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	12.32	123.20
25/02/2010	0001	ΓΚΟΛΦΙΝΟΠΟΥΛΟΣ ΙΩΑΝ.	AW3.04B.25N.B11.01.07.01	10.00	7.20	71.99
25/02/2010	0002	ΝΤΑΒΕΛΗΣ ΠΑΝΑΓΙΩΤΗΣ	AW3.04B.25N.B11.01.07.01	10.00	7.20	71.99
25/02/2010	0003	ΠΡΕΖΑΣ ΣΤΑΥΡΟΣ	AW3.04B.25N.B11.01.07.01	10.00	7.20	71.99
25/02/2010	0015	ΚΑΡΑΓΙΑΝΝΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	12.32	123.20
25/02/2010	0017	ΠΕΤΑΡΟΥΔΑΣ ΑΠΟΣΤΟΛΟΣ	AW3.04B.25N.B11.01.07.01	10.00	14.07	140.71
26/02/2010	0009	ΓΕΩΡΓΙΟΥ ΕΥΣΤΑΘΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	12.32	123.20
26/02/2010	0114	ΓΕΩΡΓΟΥΛΗΣ ΤΙΜΟΛΕΩΝ	AW3.04B.25N.B11.01.07.01	10.00	12.39	123.86
26/02/2010	0115	ΧΑΜΑΚΙΩΤΗΣ ΓΕΩΡΓΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	10.45	104.50
26/02/2010	0116	ΠΛΙΑΤΣΙΚΟΥΡΑΣ Π.	AW3.04B.25N.B11.01.07.01	10.00	8.18	81.81
26/02/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.25N.B11.01.07.01	10.00	7.66	76.56
01/03/2010	0001	ΓΚΟΛΦΙΝΟΠΟΥΛΟΣ ΙΩΑΝ.	AW3.04B.25N.B11.01.07.01	10.00	7.20	71.99
01/03/2010	0002	ΝΤΑΒΕΛΗΣ ΠΑΝΑΓΙΩΤΗΣ	AW3.04B.25N.B11.01.07.01	10.00	7.20	71.99
01/03/2010	0003	ΠΡΕΖΑΣ ΣΤΑΥΡΟΣ	AW3.04B.25N.B11.01.07.01	10.00	7.20	71.99
01/03/2010	0015	ΚΑΡΑΓΙΑΝΝΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.25N.B11.01.07.01	11.00	12.32	135.52
02/03/2010	0004	ΤΣΟΚΑΝΑΣ ΑΡΙΣΤ.	AW3.04B.25N.B11.01.07.01	10.00	7.74	77.41
02/03/2010	0005	ΛΑΛΙΩΤΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.25N.B11.01.07.01	12.00	4.13	49.56
02/03/2010	0015	ΚΑΡΑΓΙΑΝΝΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	12.32	123.20
02/03/2010	0114	ΓΕΩΡΓΟΥΛΗΣ ΤΙΜΟΛΕΩΝ	AW3.04B.25N.B11.01.07.01	10.00	12.39	123.86
02/03/2010	0115	ΧΑΜΑΚΙΩΤΗΣ ΓΕΩΡΓΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	10.45	104.50
03/03/2010	0002	ΝΤΑΒΕΛΗΣ ΠΑΝΑΓΙΩΤΗΣ	AW3.04B.25N.B11.01.07.01	13.00	7.20	93.58
03/03/2010	0005	ΛΑΛΙΩΤΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.25N.B11.01.07.01	13.00	4.13	53.69
03/03/2010	0015	ΚΑΡΑΓΙΑΝΝΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	12.32	123.20
03/03/2010	0114	ΓΕΩΡΓΟΥΛΗΣ ΤΙΜΟΛΕΩΝ	AW3.04B.25N.B11.01.07.01	10.00	12.39	123.86
03/03/2010	0115	ΧΑΜΑΚΙΩΤΗΣ ΓΕΩΡΓΙΟΣ	AW3.04B.25N.B11.01.07.01	10.00	10.45	104.50
04/03/2010	0005	ΛΑΛΙΩΤΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.25N.B11.01.07.01	0.00	4.13	0.00

1

APPENDIX 16: Bridge, Subcontractor data: Model extraction report

Κόστος

4/5/2012

Κ.Κόστους	Είδος	Περιγραφή		Ποσότητα Πραγματ.	Τιμή Μον.	Συνολική Αξία
30/04/2010	9001	Σκυρόδεμα Καθαριότητας - (m³)	AW3.04B.25N.B11.01.07.01	82.50	6.00	495.00
30/04/2010	9005	Θεμελιώσεις επί εδάφους (ραντιε)	AW3.04B.25N.B11.01.07.01	365.00	18.00	6,570.00
30/04/2010	9016	Καλουπωτό Σκυρόδεμα Πληρώσε	AW3.04B.25N.B11.01.07.01	100.00	23.00	2,300.00
30/04/2010	9075	Διάτρηση οπών μήκους 1,25μ και	AW3.04B.25N.B11.01.07.01	224.00	64.00	14,336.00
30/04/2010	9900	Απολογιστικά Ημερομίσθια Τεχνίτ	AW3.04B.25N.B11.01.07.01	19.00	115.00	2,185.00
30/04/2010	9901	Απολογιστικά Ημερομίσθια Βοηθο	AW3.04B.25N.B11.01.07.01	13.00	100.00	1,300.00
30/04/2010	9902	Απολογιστικά Ημερομίσθια Εργάτ	AW3.04B.25N.B11.01.07.01	10.00	90.00	900.00
31/05/2010	9007	Σίδηροι Οπλισμοί Πασσάλων (Κ(	AW3.04B.25N.B11.01.07.02	201,665.06	0.08	16,133.20
31/05/2010	9030	Δοκιμαστική Φόρτιση Πασσάλων	AW3.04B.25N.B11.01.07.02	0.50	7,000.00	3,500.00
31/05/2010	9031	Δοκιμή Ελέγχου Ακεραιότητας Πα	AW3.04B.25N.B11.01.07.02	0.50	25.00	12.50
31/05/2010	9041	Κατασκευή Πασσάλων Διαμέτρου	AW3.04B.25N.B11.01.07.02	64.10	50.00	3,205.00
31/05/2010	9072	Πρόσθετη τιμή για κατασκευή πας	AW3.04B.25N.B11.01.07.02	20.00	10.00	200.00
31/05/2010	9073	Εισκόμιση, εγκατάσταση και αποκ	AW3.04B.25N.B11.01.07.02	1.00	3,500.00	3,500.00
31/05/2010	9074	Κοπή οπλισμένου σκυροδέματος	AW3.04B.25N.B11.01.07.02	62.00	65.00	4,030.00
31/05/2010	9076	Κατ'αποκοπή εργασίες 1ης φάσης	AW3.04B.25N.B11.01.07.01	1.00	18,000.00	18,000.00
31/05/2010	9077	Κατ'αποκοπή εργασίες 2ης φάσης	AW3.04B.25N.B11.01.07.01	1.00	15,200.00	15,200.00
31/05/2010	9078	Προκαταβολή εργασιών κατεδάφι	AW3.04B.25N.B11.01.07.01	1.00	12,000.00	12,000.00
31/05/2010	9079	Πρόσθετη τιμή κατ'αποκοπή μετά	AW3.04B.25N.B11.01.07.01	1.00	22,800.00	22,800.00
31/05/2010	9900	Απολογιστικά Ημερομίσθια Τεχνίτ	AW3.04B.25N.B11.01.07.02	40.00	115.00	4,600.00
31/05/2010	9901	Απολογιστικά Ημερομίσθια Βοηθο	AW3.04B.25N.B11.01.07.02	32.00	100.00	3,200.00
31/05/2010	9902	Απολογιστικά Ημερομίσθια Εργάτ	AW3.04B.25N.B11.01.07.02	24.00	90.00	2,160.00
30/06/2010	9007	Σίδηροι Οπλισμοί Πασσάλων (Κ(	AW3.04B.25N.B11.01.07.02	135,841.00	0.08	10,867.28
30/06/2010	9035	Κατασκευή Πασσάλων Διαμέτρου	AW3.04B.25N.B11.01.07.02	93.08	39.00	3,630.12
30/06/2010	9041	Κατασκευή Πασσάλων Διαμέτρου	AW3.04B.25N.B11.01.07.02	919.91	50.00	45,995.50
30/06/2010	9072	Πρόσθετη τιμή για κατασκευή πας	AW3.04B.25N.B11.01.07.02	684.39	10.00	6,843.90
30/06/2010	9900	Απολογιστικά Ημερομίσθια Τεχνίτ	AW3.04B.25N.B11.01.07.02	15.00	115.00	1,725.00
30/06/2010	9901	Απολογιστικά Ημερομίσθια Βοηθο	AW3.04B.25N.B11.01.07.02	15.00	100.00	1,500.00
30/06/2010	9902	Απολογιστικά Ημερομίσθια Εργάτ	AW3.04B.25N.B11.01.07.02	14.00	90.00	1,260.00
31/07/2010	9001	Σκυρόδεμα Καθαριότητας - (m³)	AW3.04B.25N.B11.01.07.03	26.00	6.00	156.00

1

APPENDIX 17: Bridge, Material data: Model extraction report

Κόστος 4/5/2012

Κ.Κόστους	Είδος	Περιγραφή		Ποσοτητα Πραγματ.	Τιμη Μον.	Συνολική Αξία
04/05/2010	0002	Σκυρόδεμα C 16-20	AW3.04B.25N.B11.01.07.01	160.50	56.47	9,063.44
04/05/2010	0003	Σκυρόδεμα C 12-15	AW3.04B.25N.B11.01.07.01	435.00	52.04	22,637.40
04/05/2010	0004	Σκυρόδεμα C 8-10	AW3.04B.25N.B11.01.07.01	1.00	45.52	45.52
04/05/2010	0018	Concrete Pipe Σ75 (m)	AW3.04B.25N.B11.01.07.01	250.00	0.00	0.00
04/05/2010	0032	B25 πασσάλων	AW3.04B.25N.B11.01.07.01	0.00	65.69	0.00
04/05/2010	0033	Οπλισμός Πασσαλων	AW3.04B.25N.B11.01.07.01	0.00	3.26	0.00
27/05/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	20.00	65.69	1,313.80
31/05/2010	0003	Σκυρόδεμα C 12-15	AW3.04B.25N.B11.01.07.02	3.00	52.04	156.12
31/05/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	45.00	65.69	2,956.05
31/05/2010	0033	Οπλισμός Πασσαλων	AW3.04B.25N.B11.01.07.02	15,480.00	0.57	8,823.60
01/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	44.00	65.69	2,890.36
02/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	44.00	65.69	2,890.36
03/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	24.00	65.69	1,576.56
04/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	44.00	65.69	2,890.36
07/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	22.00	65.69	1,445.18
08/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	42.00	65.69	2,758.98
09/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	37.00	65.69	2,430.53
10/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	59.00	65.69	3,875.71
11/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	47.00	65.69	3,087.43
12/06/2010	0003	Σκυρόδεμα C 12-15	AW3.04B.25N.B11.01.07.02	5.00	52.04	260.20
12/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	20.00	65.69	1,313.80
13/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	21.00	65.69	1,379.49
14/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	54.00	65.69	3,547.26
15/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	92.00	65.69	6,043.48
16/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	36.00	65.69	2,364.84
17/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	18.00	65.69	1,182.42
18/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	27.00	65.69	1,773.63
21/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	23.00	65.69	1,510.87
22/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλωι	AW3.04B.25N.B11.01.07.02	46.00	65.69	3,021.74

1

APPENDIX 18: Underpass, Personnel data: Model extraction report

Κόστος 8/8/2011

Κ.Κόστους	Είδος	Περιγραφή		Ποσότητα Πραγματ.	Τιμή Μον.	Συνολική Αξία
01/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
07/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
08/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
09/06/2010	0015	ΚΑΡΑΓΙΑΝΝΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.22N.B11.02.02.01	10.00	12.32	123.20
09/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
11/06/2010	0015	ΚΑΡΑΓΙΑΝΝΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.22N.B11.02.02.01	10.00	12.32	123.20
11/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
12/06/2010	0015	ΚΑΡΑΓΙΑΝΝΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.22N.B11.02.02.01	8.00	12.32	98.56
12/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	8.00	7.66	61.25
12/06/2010	0130	ΛΥΜΠΕΡΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	8.00	8.51	68.06
13/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	8.00	7.66	61.25
14/06/2010	0115	ΧΑΜΑΚΙΩΤΗΣ ΓΕΩΡΓΙΟΣ	AW3.04B.22N.B11.02.02.01	10.00	10.45	104.50
14/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	8.00	7.66	61.25
15/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
17/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
17/06/2010	0123	ΝΙΚΟΛΟΠΟΥΛΟΣ ΗΛΙΑΣ	AW3.04B.22N.B11.02.02.01	10.00	12.33	123.25
18/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	8.00	7.66	61.25
21/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
21/06/2010	0123	ΝΙΚΟΛΟΠΟΥΛΟΣ ΗΛΙΑΣ	AW3.04B.22N.B11.02.02.01	10.00	12.33	123.25
22/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
25/06/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
30/06/2010	0015	ΚΑΡΑΓΙΑΝΝΗΣ ΔΗΜΗΤΡΙΟΣ	AW3.04B.22N.B11.02.02.01	10.00	12.32	123.20
01/07/2010	0017	ΠΕΤΑΡΟΥΔΑΣ ΑΠΟΣΤΟΛΟΣ	AW3.04B.22N.B11.02.02.01	10.00	14.07	140.71
01/07/2010	0117	ΤΕΡΖΟΠΟΥΛΟΣ ΚΩΝ/ΝΟΣ	AW3.04B.22N.B11.02.02.01	10.00	7.66	76.56
02/07/2010	0123	ΝΙΚΟΛΟΠΟΥΛΟΣ ΗΛΙΑΣ	AW3.04B.22N.B11.02.02.01	8.00	12.33	98.60
05/07/2010	0123	ΝΙΚΟΛΟΠΟΥΛΟΣ ΗΛΙΑΣ	AW3.04B.22N.B11.02.02.01	10.00	12.33	123.25
06/07/2010	0006	ΚΟΛΟΜΟΔΗΣ ΓΕΩΡΓΙΟΣ	AW3.04B.22N.B11.02.02.01	11.00	4.13	45.43
06/07/2010	0123	ΝΙΚΟΛΟΠΟΥΛΟΣ ΗΛΙΑΣ	AW3.04B.22N.B11.02.02.01	10.00	12.33	123.25
06/07/2010	0139	ΤΑΣΣΟΠΟΥΛΟΣ ΑΝΔΡΕΑΣ	AW3.04B.22N.B11.02.02.01	10.00	8.00	80.01

1

APPENDIX 19: Underpass, Subcontractors data: Model extraction report

Κόστος

8/8/2011

Κ.Κόστους	Είδος	Περιγραφή		Ποσότητα Πραγματ.	Τιμή Μον.	Συνολική Αξία
31/05/2010	9007	Σίδηροι Οπλισμοί Πασσάλων (Κε	AW3.04B.22N.B11.02.02.01	45,384.00	0.08	3,630.72
31/05/2010	9041	Κατασκευή Πασσάλων Διαμέτρου	AW3.04B.22N.B11.02.02.01	64.98	50.00	3,249.00
31/05/2010	9073	Εισκόμιση, εγκατάσταση και αποκ	AW3.04B.22N.B11.02.02.01	1.00	3,500.00	3,500.00
30/06/2010	9001	Σκυρόδεμα Καθαριότητας - (m³)	AW3.04B.22N.B11.02.02.02	4.00	6.00	24.00
30/06/2010	9041	Κατασκευή Πασσάλων Διαμέτρου	AW3.04B.22N.B11.02.02.01	494.64	50.00	24,732.00
30/06/2010	9073	Εισκόμιση, εγκατάσταση και αποκ	AW3.04B.22N.B11.02.02.01	1.00	3,500.00	3,500.00
31/07/2010	9007	Σίδηροι Οπλισμοί Πασσάλων (Κε	AW3.04B.22N.B11.02.02.01	115,292.00	0.08	9,223.36
31/07/2010	9008	Σίδηροι Οπλισμοί Φορέων Τοιχείω	AW3.04B.22N.B11.02.02.02	27,246.16	0.13	3,542.00
31/07/2010	9041	Κατασκευή Πασσάλων Διαμέτρου	AW3.04B.22N.B11.02.02.01	610.29	50.00	30,514.50
31/07/2010	9902	Απολογιστικά Ημερομίσθια Εργάτι	AW3.04B.22N.B11.02.02.02	5.00	90.00	450.00
31/08/2010	9001	Σκυρόδεμα Καθαριότητας - (m³)	AW3.04B.22N.B11.02.02.02	59.50	6.00	357.00
31/08/2010	9014	Υπόγειες Διαβάσεις, Τοιχεία Πλάκ	AW3.04B.22N.B11.02.02.02	20.29	40.00	811.60
30/09/2010	9001	Σκυρόδεμα Καθαριότητας - (m³)	AW3.04B.22N.B11.02.02.02	15.00	6.00	90.00
30/09/2010	9004	Κεφαλόδεσμοι (m³)	AW3.04B.22N.B11.02.02.01	36.90	20.00	738.00
30/09/2010	9008	Σίδηροι Οπλισμοί Φορέων Τοιχείω	AW3.04B.22N.B11.02.02.02	106,920.00	0.13	13,899.60
30/09/2010	9900	Απολογιστικά Ημερομίσθια Τεχνίτι	AW3.04B.22N.B11.02.02.02	8.00	115.00	920.00
30/09/2010	9901	Απολογιστικά Ημερομίσθια Βοηθο	AW3.04B.22N.B11.02.02.02	8.00	100.00	800.00
30/09/2010	9902	Απολογιστικά Ημερομίσθια Εργάτι	AW3.04B.22N.B11.02.02.02	7.00	90.00	630.00
31/10/2010	9001	Σκυρόδεμα Καθαριότητας - (m³)	AW3.04B.22N.B11.02.02.04	27.00	6.00	162.00
31/10/2010	9087	Πλάκες πρόσβασης	AW3.04B.22N.B11.02.02.04	49.10	25.00	1,227.50
		Γενικά Σύνολα:				102,001.28

1

APPENDIX 20: Underpass, Material data: Model extraction report

Κόστος

8/8/2011

Κ.Κόστους	Είδος	Περιγραφή			Ποσότητα Πραγματ.	Τιμή Μον.	Συνολική Αξία
26/04/2010	0002	Σκυρόδεμα C 16-20	AW3.04B.22N.B11.02.02.03		8.00	56.47	451.76
29/05/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		20.00	65.69	1,313.80
30/05/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		42.00	65.69	2,758.98
31/05/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		54.00	65.69	3,547.26
01/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		51.00	65.69	3,350.19
02/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		60.00	65.69	3,941.40
03/06/2010	0003	Σκυρόδεμα C 12-15	AW3.04B.22N.B11.02.02.01		31.50	52.04	1,639.26
03/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		68.00	65.69	4,466.92
04/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		24.00	65.69	1,576.56
07/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		54.00	65.69	3,547.26
08/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		54.00	65.69	3,547.26
09/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		54.00	65.69	3,547.26
17/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		18.00	65.69	1,182.42
18/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		27.00	65.69	1,773.63
21/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		54.00	65.69	3,547.26
30/06/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		72.00	65.69	4,729.68
01/07/2010	0003	Σκυρόδεμα C 12-15	AW3.04B.22N.B11.02.02.01		16.00	52.04	832.64
01/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		36.00	65.69	2,364.84
02/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		36.00	65.69	2,364.84
05/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		63.00	65.69	4,138.47
06/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		63.00	65.69	4,138.47
07/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		90.00	65.69	5,912.10
09/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		54.00	65.69	3,547.26
10/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		27.00	65.69	1,773.63
11/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		27.00	65.69	1,773.63
12/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		61.00	65.69	4,007.09
13/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		60.00	65.69	3,941.40
14/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		62.00	65.69	4,072.78
15/07/2010	0006	Σκυρόδεμα C 20-25 s4 Πασσάλων	AW3.04B.22N.B11.02.02.01		60.00	65.69	3,941.40

1

APPENDIX 21: Earth Mass Haul Diagram