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Schedule performance measurement in EPC projects: Earned schedule approach beyond Earned Value Management – A case study at SARPI

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ABSTRACT:

EPC projects may be considered among the most intricate and resource-intensive ventures within industry, although their monitoring practice relies mainly on classic schedule indicators, which, however, possess certain structural drawbacks. The research analyzes whether the Earned Schedule technique is based on more accurate criteria for assessing schedule performance and forecast the project duration than the classic EVM indicators are in the EPC project management process at SARPI, an Algerian publicly-owned industrial construction company.

For the purpose of conducting this study, a mixed-methods approach was chosen, incorporating semi-structured interviews conducted with experts on project control and quantitative empirical analysis using both EVM and ES indicators tested over three fully-executed EPC projects in three distinct tests.

The results of this research show the uniform adoption of EVM indicators by all the institutions, coupled with the total absence of any knowledge about ES. On the empirical level, ES outperformed classic EVM in three major aspects: its greater ability to diagnose a schedule deviation during late stages of the project when SPI($) tends to converge and become less reliable, its ability to reveal schedule deviation SV in its true form with time-based variance not being subjected to any distortion, and more precise forecast of project duration (IEAC) in the early stages when preventive actions can still be undertaken.

Keywords: Earned Value Management, Earned Schedule, EPC Projects, Schedule Performance Index, Duration Forecasting, Project Control

RÉSUMÉ :

Les projets EPC peuvent être considérés parmi les réalisations les plus complexes et les plus exigeantes en ressources au sein de l'industrie, bien que leur pratique de suivi repose principalement sur des indicateurs d'avancement classiques, lesquels présentent néanmoins certaines lacunes structurelles. Cette recherche analyse si la technique de « Calendrier Acquis » se fonde sur des critères plus précis pour évaluer la performance calendaire et prévoir la durée du projet, par rapport à la technique « Gestion de la Valeur Acquise » classique, dans le processus de gestion de projets EPC à SARPI, une entreprise algérienne de construction industrielle à capitaux publics.

Dans le but de mener cette étude, une approche mixte a été choisie, intégrant des entretiens semi-directifs conduits auprès d'experts en contrôle de projet, ainsi qu'une analyse empirique quantitative utilisant à la fois les indicateurs « Gestion de la Valeur Acquise » et « Calendrier Acquis », Les indicateurs sont testés sur trois projets EPC achevés, à travers trois tests distincts.

Les résultats de cette recherche montrent l'adoption uniforme des indicateurs de la méthode « Gestion de la Valeur Acquise » par l'ensemble des institutions, couplée à une absence totale de connaissance de la méthode « Calendrier Acquis ». Sur le plan empirique, la méthode « Calendrier Acquis » a surpassé la méthode « Gestion de la Valeur Acquise » classique sur trois aspects majeurs : sa plus grande capacité à diagnostiquer un écart d'avancement durant les phases tardives du projet, lorsque l'Indice de Performance des Délais tend à converger et à perdre en fiabilité ; sa capacité à révéler l'écart d'avancement sous sa forme réelle, exprimé en écart temporel non soumis à aucune distorsion ; et une prévision plus précise de la durée du projet (IEAC) dans les phases initiales, lorsque des actions préventives peuvent encore être entreprises.

Mots-clés : Gestion de la Valeur Acquise, Calendrier Acquis, Projets EPC, Indice de Performance des Délais, Prévision de Durée, Contrôle de Projet

الملخص:

تعتبر مشاريع (الهندسة المشتريات والانشاءات) من بين اكثر المشاريع تعقيدا واستهلاكا للموارد في القطاع الصناعي, رغم ان متابعتها تعتمد اساسا على مؤشرات الجدولة التقليدية, والتي تظهر بعض القصور الهيكلي. تهدف هذه الدراسة الى تحليل ما اذا كانت تقنية (الجدولة المكتسبة) تعتمد على معايير اكثر دقة لتقييم الاداء الزمني والتنبؤ بمدة انجاز المشروع مقارنة بمؤشرات (ادارة القيمة المكتسبة) التقليدية, وذلك في اطار ادارة مشاريع (الهندسة المشتريات والانشاءات) داخل الشركة الجزائرية لانجاز المشاريع الصناعية (صاربي), وهي شركة جزائرية عمومية متخصصة في البناء الصناعي. ولإنجاز هذه الدراسة، تم اعتماد منهجية بحث مختلطة تجمع بين المقابلات شبه المهيكلة مع خبراء في مراقبة المشاريع، والتحليل الكمي التطبيقي باستخدام كل من مؤشرات (ادارة القيمة المكتسبة) و(الجدولة المكتسبة)، حيث تم اختبارهما على ثلاثة مشاريع (الهندسة المشتريات والانشاءات) مكتملة التنفيذ من خلال ثلاث حالات دراسية مستقلة. أظهرت نتائج البحث وجود اعتماد موحّد لمؤشرات (ادارة القيمة المكتسبة) داخل الشركة الجزائرية العمومية المتخصصة في المشاريع الصناعية (صاربي), مقابل غياب تام لأي معرفة أو استخدام لتقنية (الجدولة المكتسبة). وعلى المستوى التطبيقي، أثبتت تقنية (الجدولة المكتسبة) تفوقها على (ادارة القيمة المكتسبة) التقليدية في ثلاثة جوانب رئيسية: أولًا، قدرتها الأكبر على تشخيص الانحرافات الزمنية خلال المراحل المتأخرة من المشروع، حين يميل (مؤشر أداء الجدول الزمني) إلى التقارب ويصبح أقل موثوقية؛ ثانيًا، قدرتها على إظهار (الانحراف الزمني) بصورته الحقيقية من خلال قياس زمني غير خاضع لأي تشويه؛ وثالثًا، تقديمها توقعًا أكثر دقة لمدة إنجاز المشروع بمؤشر (التقدير المستقل عند الإنجاز) خلال المراحل المبكرة، حيث لا تزال إمكانية اتخاذ الإجراءات التصحيحية متاحة.

الكلمات المفتاحية:

الجدولة المكتسبة، ادارة القيمة المكتسبة، مشاريع الهندسة المشتريات والانشاءات، مؤشر أداء الجدول الزمني، التنبؤ بمدة المشروع.

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LIST OF ABBREVIATIONS:

AC: Actual Cost

AT: Actual Time

BAC: Budget at Completion

CPM: Critical Path Method

CPI: Cost Performance Index

CV: Cost Variance

DIFF(EV): Percent Difference of IEAC(EV) from Final Duration

DIFF(PV): Percent Difference of IEAC(PV) from Final Duration

DIFF(ES): Percent Difference of IEAC(ES) from Final Duration

EAC: Estimate at Completion

EPC: Engineering, Procurement, and Construction

ES: Earned Schedule

EV: Earned Value

EVM: Earned Value Management

IEAC: Independent Estimate at Completion

IEAC(ES): Duration Forecast Using Earned Schedule Method

IEAC(EV): Duration Forecast Using Earned Value Method

IEAC(PV): Duration Forecast Using Planned Value Method

MRQ: Main Research Question

PD: Planned Duration

PERT: Program Evaluation and Review Technique

PMI: Project Management Institute

PMIS: Project Management Information System

PV: Planned Value

SARPI : Société Algérienne de Réalisation de Projets Industriels

SPI ($): Schedule Performance Index (Cost-Based)

SPI(t): Schedule Performance Index (Time-Based)

SV ($): Schedule Variance (Cost-Based)

SV(t): Schedule Variance (Time-Based)

WBS: Work Breakdown Structure

INTRODUCTION

Background of the study:

The ever-growing complexity of the industrial project environment has prompted a review of the systems and methods utilized for project monitoring, controlling, and forecasting. In the Engineering, Procurement, and Construction (EPC) industry, whereas (Akhtar, 2020) notes, projects have long durations, high budgets, and are highly exposed to risks of cost overruns and delays, the accuracy of performance indicators becomes the key factor determining the outcome of a project. In the Algerian context, where projects in the EPC industry are mostly conducted by public companies such as SARPI, which operate on a grand scale and are subject to serious budget and time pressures, the efficiency of the project control system plays a vital role.

Within this situation, Earned Value Management (EVM) is increasingly recognized as one of the major systems utilized in integrated project performance control, whereby performance information regarding scope, costs, and schedule can be aggregated and analyzed together as part of an integrated system. As a result, through schedule-related indicators like Schedule Performance Index SPI($) and Schedule Variance SV($), EVM provides a structured framework for assessing the extent of deviations from the plan and the level of progress made by the project. On the other hand, as (Ballesteros-Pérez & Elamrousy, 2018) point out, one of the limitations that are commonly associated with the application of Earned Value Management is related to the way in which the schedule-based indicators in EVM tend to converge towards neutral values as the end of a project approaches due to budget at completion.

To address this issue, Lipke proposed the Earned Schedule (ES) technique, which presents an approach to evaluating schedule performance through time metrics rather than cost metrics. As (Lipke, 2003) establishes, with the use of metrics such as SPI(t), SV(t), and duration prediction formulas like IEAC(ES), the earned schedule technique provides a theoretically sound foundation for assessing schedule performance across the entire lifecycle of the project. Although the literature has started supporting the benefits of ES metrics, their application to actual data on EPC projects in the Algerian setting is rare, creating a notable research void that the current study seeks to fill.

The dissertation has been divided into three main chapters. Chapter one begins by laying down the theoretical background of this study through elaborating on the historical evolution of the subject area, including the fundamentals of project management, basics of the Earned

Value Management technique, and its critical indicators and constraints. Additionally, the chapter outlines the basics of the Earned Schedule method developed by Lipke. Chapter two lays down the methodology used for undertaking this study including the data source used, interviewing methodology, EVM and ES calculations procedure, and the three tests.

Research Objectives:

The overall goal of this research is to conduct an empirical evaluation of diagnostic effectiveness and forecasting accuracy of EVM schedule indicators in comparison with Earned Schedule indicators on the basis of actual performance data for three fully completed EPC projects implemented under SARPI and evaluate whether the latter type of indicators is more effective and practical means of measuring schedule performance and forecasting project duration throughout the entire project lifecycle.

In particular, this research seeks to achieve the following objectives:

- Specifically investigate the differences in behavioral pattern of SPI(t) and SPI($) throughout the entire duration of an EPC project and find out which one preserves diagnostic significance in the last phases of implementation better.
- Identify the point of divergence of SV(t) and SV($) and find out how it influences schedule performance management in practical terms.
- Compare the accuracy and stability of IEAC(EV), IEAC(PV) and IEAC(ES) in their ability to forecast the duration of the project during each reporting period for all three projects and find out which one gives better results.

Research Problem:

In spite of the popularity of the use of EVM as a system of project management control, there remains a structural drawback of schedule-related indicators which limit the information value of these measures right at the moment it becomes crucial – that is, towards the end of the project's lifecycle. This challenge holds special relevance for EPC projects because the occurrence of schedule delays is relatively common, costly, and even harder to rectify. There have been suggestions made regarding the application of Earned Schedule

technique, as a way of overcoming this challenge in literature, but no empirical comparison between it and traditional EVM has ever been conducted based on actual EPC projects from Algeria.

The following research question is thus formulated:

To what extent does the Earned Schedule method provide a more reliable basis for schedule performance measurement and duration forecasting than traditional EVM indicators in EPC project management?

Secondary Research Questions:

- What are the current perceptions of the merits and drawbacks of EVM among EPC project managers at SARPI, and is the Earned Schedule concept known to them?
- Are SPI(t) and SPI($) distinct during the implementation of EPC projects as they approach completion, and is SPI(t) a more reliable indicator of schedule slippage in the later phases of execution?
- At what stage in the project cycle do SV(t) and SV($) begin to differ, and how does such differentiation affect the reliability of schedule management indicators that can be derived from them?
- Can IEAC(ES) forecast project durations better than IEAC(EV) and IEAC(PV) across all stages in the life cycle of an EPC project, and from what stage onwards does such superiority become practically meaningful?

The reason for choosing the topic:

Projects under the EPC delivery model represent some of the most complicated and capital-intensive operations within the industrial sector, necessitating a reliable methodology that can manage not only cost but also time performances at once. Considering the aspects of financial management, any delays in project schedules result in increased costs and reduced ROI. The performance of the schedule is thus important from the financial standpoint as much as from an operational perspective. Given the fact that SARPI employs only conventional EVM, an approach which is acknowledged to have inherent structural weaknesses regarding schedule monitoring, especially towards the concluding stages of implementation, this study is inspired by the belief that the use of Earned Schedule could address such inadequacies.

CHAPTER 1: STATE OF THE ART

Introduction of chapter 1:

This chapter lays out the theoretical background behind this study. First, it reviews the history of the emergence and evolution of the project management profession. Then it proceeds to review some particular problems associated with cost and schedule management on EPC project projects. Next, the chapter introduces Earned Value Management (EVM) and explains its major tenets and performance indices. After this, it outlines the limits of the use of EVM as far as schedule estimation is concerned. And lastly, it introduces Earned Schedule as a time-based counterpart of EVM and describes its performance indices as well as its advantages for forecasting.

1 The development and History of Project Management

Project management has become a structured concept that has grown out of individual practices and developed into models that depend on their context. Many authors, including (Garel, 2013), describe the development of project management over time and argue that for centuries up to the early twentieth century, project management history remained connected to technical domains, implying that project-related activities had no organizational and managerial value. It took place in the 1950s and 1960s, (Fleming & Koppelman, 2010) note that the process began to take shape as an independent field of management associated with government and military projects, such as the Polaris missile system and NASA initiatives. The need for a developed discipline arose due to specific features of managing complicated technical projects, whereas (Garel, 2013) argues, sectoral peculiarities played a subordinate role.

As far as the formalization of the methodological aspects of project management was concerned, the Project Management Body of Knowledge (PMI, 2021) highlights that the demand came from institutions as the clients of the field. (Phillips et al., 1983) identified the emergence of basic scheduling methods such as Critical Path Method (CPM) and Program Evaluation and Review Technique (PERT) as a key point during this period, which helped in defining approaches to project management methodologies. Nevertheless, as (Turner et al., 2009) often state in academic literature, there is still no organization-wide project management approach that can be considered universal because of the different types of projects and problems faced.

2 Project Cost Management in Complex Environments

Cost control represents one of the most vital aspects of project success, and grasping its mechanics, difficulties, and context is crucial to recognizing the necessity for an effective means of tracking.

2.1 Process, Significance, and Integration Issues

The Project Management Body of Knowledge (PMI, 2021) establishes that the success of a project can be determined using two essential factors, namely good cost management and value generation and maximization. (Kelly et al., 2015) note that various research works have identified that cost management involves important processes such as cost estimation, budgeting, financial planning, and cost control, while value management seeks to achieve maximum project benefits considering costs, times, and resource limitations.

As (Love et al., 2015) point out, even with various cost management approaches and methods available, the issue of cost overrun and project delay continues to plague the process of project management. (Cantarelli et al., 2010) found through empirical studies that most projects do not conform to their budget projections and do not produce the expected value, something that has been found in various industries ranging from construction, infrastructure development, defense systems, to IT sectors.

2.2 Cost Overruns and Project Challenges in Algeria

There are many studies that have found the cost performance of oil and gas projects varies greatly, depending on the project scale and geographical regions. According to (Rui et al., 2017), oil and gas projects, whose scale is large-scale, face more cost overruns than smaller projects, due to higher complexity and higher uncertainty in large-scale projects. There are also geographic differences in the cost performance of oil and gas projects, where oil and gas projects in Africa face greater cost overruns than those in Europe. This is mainly because local content policy, professional practice, manpower, and political stability affect cost performance differently depending on geographic regions.

In particular, in the case of Algeria, (Rachid et al., 2019) have examined the causes for the delay of large-scale construction projects, where they categorized a total of 59 causes into nine categories depending on their sources. These factors have been ranked through the conduct of surveys among 16 building owners, 16 contractors, and 20 consultants, revealing that there were three factors which featured consistently among all of them. These factors include the delay in issuing changes in the order, the delay in issuing variation order due to additional quantities, and initiating the construction process before completing the design process. As far as the Algerian context is concerned, delay because of owner-caused reasons was found to be more critical, a finding that is very relevant, particularly since most of the building projects and infrastructure development works in Algeria are undertaken under public sector management.

3 EPC Contracts: Nature, Risk Allocation, and Management Implications

(Hansen, 2015) describes EPC (Engineering, Procurement, and Construction) contracting as a model where the contractor takes complete responsibility for design, procurement, and construction activities, and is generally employed in power plant, factory, gas field development, infrastructure, and industrial projects. As (Loots & Henchie, 2007) note, EPC contracting is a project delivery system whereby employer risks are transferred to the contractor, providing certainty in costs and schedules for project sponsors but requiring full managerial control during all stages of the project. (Hansen, 2015) further argues that the very attributes of EPC contracts, i.e., one-stop responsibility and total risk transfer, pose challenges both in increasing the complexity of the project and in limiting flexibility in cost control by virtue of fixed pricing, narrow variation scope, and high-performance expectations amidst multiple-stage interactions and complex interdependencies among various stakeholders.

3.1 The EPC Project Life Cycle

As (Hansen, 2015) explains, the project life cycle refers to an ordered set of phases that are usually sequential but may overlap as well, depending on the required number and the names of the phases needed, based on organizational management and control, the nature of the project, and its domain. (Turner et al., 2009) further note that its nature and composition depend on the unique qualities of the organization, the business industry, or the technology utilized, although each project begins and ends at a certain point, but with a different set of activities in between. (Hansen, 2015) specifies that as for EPC project delivery, the life cycle is typically split into three interdependent stages, which include engineering, procurement, and construction. The engineering stage starts with concept design and includes basic and detailed engineering, work planning, and other activities, and it largely shapes all other stages, since many important and irrevocable decisions have to be taken at that stage. The author also notes that the procurement stage involves the purchasing of materials and equipment needed to perform the project not just to construct but to operate the resulting system. (Akhtar, 2020) defines the construction stage as including both physical work, such as site preparation, fabrication, erection, testing, and commissioning, and non-physical work, such as planning, controlling, supervision, inspection, and contract management.

3.2 Challenges in Managing EPC Projects

EPC projects face a distinct set of managerial challenges that compound their inherent complexity and directly expose them to schedule and cost risks.

3.2.1 Project Complexity and Interface Management

(Akhtar, 2020) observes that it is common for large scale engineering procurement construction projects to be affected by delays, cost overruns, and even failure because of the structural complexity of such projects and the fact that some project scopes are outsourced entirely to a single company that might not be able to handle the project well. Assigning mega projects involving many billions of dollars to just one EPC contractor represents an over-concentration of risks involved in such projects. On the other hand, (Akhtar, 2020) further notes that breaking down the projects into several EPC projects to several contractors has led to under-performance in most cases because of improper interface management. Proper interface management is a key factor of success; poor interface management results in cost overruns, schedule slips, lack of work front availability, contractor conflict, misalignments on the master schedule and high amount of reworks.

3.2.2 Weak Front-End Planning

As (Gibson et al., 2006) argue, inadequate planning often leads to either failure or significant delays in the project process, making projects vulnerable to unanticipated risks. (Akhtar, 2020) mentioned that at the outset of the process, the contractor must ensure that the project team thoroughly grasps certain aspects: milestone completions, delivery deadlines, budgetary concerns, allocation of roles and duties, and modes of implementation. After winning the contract, the contractor must appoint planning experts who will help formulate an execution plan considering resource requirements from initial to final stages of the project.

3.2.3 Aggressive and Unrealistic Schedules

(Akhtar, 2020) observes that aggressive and unrealistic schedules are imposed on EPC agreements by clients in order to satisfy their business needs, which involve refusing realistic Front-End Engineering Design (FEED) schedule estimates offered by the consultant. (Akhtar, 2020) further notes that clients put such pressure on EPC contractors that the unrealistic schedule becomes a criterion for participation in bidding, forcing bidders to accept unreasonable schedules while being fully aware of all risks involved (optimism bias in project scheduling according to the literature). According to (Akhtar, 2020), after contract award, it would be necessary for contractors to prepare comprehensive CPM schedules highlighting critical paths, analyze their schedules and identify realistic time frames for completing projects, and communicate all assumptions regarding planning with the client. Inappropriate schedule compression means taking resources from critical path activities and shifting them towards non-critical paths, thus jeopardizing project success.

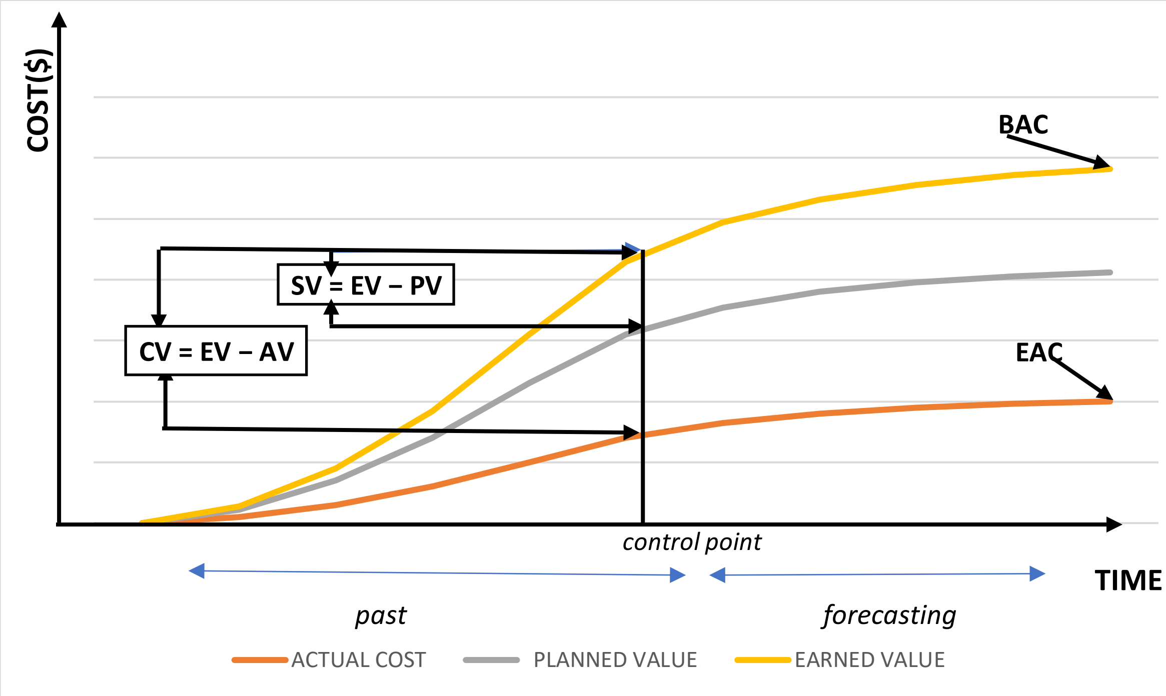
4 Earned Value Management: Principles, Indicators, and Empirical Evidence

EVM is built upon a structured set of core indicators that together enable integrated monitoring of both cost and schedule performance throughout the project lifecycle.

4.1 Conceptual Framework and Core Indicators

The Project Management Body of Knowledge (PMI, 2021) recognizes Earned Value Management (EVM), sometimes referred to as Earned Value Analysis (EVA), as one of the most advanced and validated methods for integrated project performance management and control. As (Kim et al., 2003) explain, the key idea behind this approach is to combine scope, scheduling, and cost-related data into an integral analysis allowing a project manager to evaluate project performance, identify deviations from the plan, and undertake appropriate actions as the basis for predicting the ultimate cost and duration results. (Eirgash, 2021) identifies three major indices used in EVM: Planned Value (PV), which denotes the budgeted cost of work planned to be performed over a specific time frame; Earned Value (EV), representing the budgeted cost of work accomplished; and Actual Cost (AC) reflecting actual expenditures. Based on these three indices, EVM allows one to calculate a number of indices related to project performance variances and performance indices.

Figure 1: Key metrics of the EVM technique



Source : Elaborated by Authors, adapted from (Proaño-Narváez et al., 2022)

Table 1: EVM Metrics calculations

Term	**Description**	**Interpretation**
PV (BCWS)	Planned Value	It is the budgeted cost for the work scheduled to be completed on an activity or WBS component in a particular time. It is obtained from the cash flow diagram (The S-curve).
EV (BCWP)	Earned Value	It is the budgeted amount for the work accomplished on the schedule activity or work breakdown structure (WBS) component during a given time.
AC (ACWP)	Actual Cost	It is resolved from accounting records that keeps record of actual expenditure money, that means it is secret and actual money spent by the contractor.

Term	Description	Interpretation
BAC	Budget at Completion	The total approved budget when the scope of the project is completed.
EAC	Estimate at Completion	The expected total cost of the project when the defined scope of work is completed.
ETC	Estimate to Complete	The expected extra cost necessary to finish the project.
Cost Variance (CV)	EV − AC	Negative means over budget, Positive means under budget
Schedule Variance (SV)	EV − PV	Negative means behind schedule, Positive means ahead of schedule
Cost Performance Index (CPI)	EV / AC	More than 1 means Profit and less than 1 means loss.
Schedule Performance Index (SPI)	EV / PV	More than 1 means ahead of schedule and less than 1 means behind the schedule.

Source : Elaborated by Authors, adapted from (Eirgash, 2021)

4.2 Estimate of Final Program Duration

As (Lipke, 2009) defines, another important measure relating to the schedule performance that can be estimated using EVM indicators is the independent estimate at completion (IEAC(t)). The measure estimates the duration of the program completion process with respect to the elapsed time and the estimation of work to be accomplished within the program. The widely used formula for IEAC(t) is defined by the elapsed time and the forecasted duration of remaining work. This can be calculated as follows:

$$IEAC(t)(EV) = AT + \frac{BAC - EV}{PVav}$$

$$IEAC(t)(PV) = AT + \frac{BAC - EV}{EVav}$$

Where

AT= actual time when PV and EV are reported

There are two common types of work rates used to calculate the duration of final program completion. They include average planned value PV(av) and average earned value EV(av). Value of PV(av) represents the performance of programs that progress according to plan while EV(av) represents the performance of programs following current SPI trend (Lipke, 2009b). The formulas for both work rates are presented below and have been used for calculation of IEAC(t)_{PV} and IEAC(t)_{EV}:

$$PVav = \frac{PVcum}{n}$$

$$EVav = \frac{EVcum}{n}$$

Where

- AT = actual time when PV and EV are reported
- PV_{cum} = cumulative value of PV
- EV_{cum} = cumulative value of EV
- n = number of time periods elapsed

4.3 Empirical Studies on EVM Effectiveness

The empirical studies on the effectivity of EVM use in construction project management consistently show similar trends. (Proaño-Narváez et al., 2022) carried out a comparative analysis of two case studies and found that EVM use in projects helped achieve better results in terms of both cost and time efficiency compared to projects where no performance measurement was utilized. The project in which EVM was implemented successfully resulted in a 14.20% economic gain and completion on schedule due to the realistic and timely-updated baseline, effective resource management, and better project coordination. On the contrary, the same authors further found that the project in which EVM was not used was completed on schedule but saw 3.24% extra costs due to unrealistically high baseline requirements, ineffective resource management, and lack of familiarity with project management tools.

As (Cioffi, 2006) notes, even with these strengths, there are instances where the success of EVM depends on the knowledge and ability of the project manager in understanding the meaning of indicator data and taking appropriate actions. In addition, accurate and effective cost recording processes have to be put in place for successful application of EVM. (Henderson, 2003) further found that there are instances where EVM has been found to work better as a cost control measure rather than as a scheduling technique since the CPI is relatively stable above 20% complete.

4.4 Structural Limitations of EVM Schedule Indicators

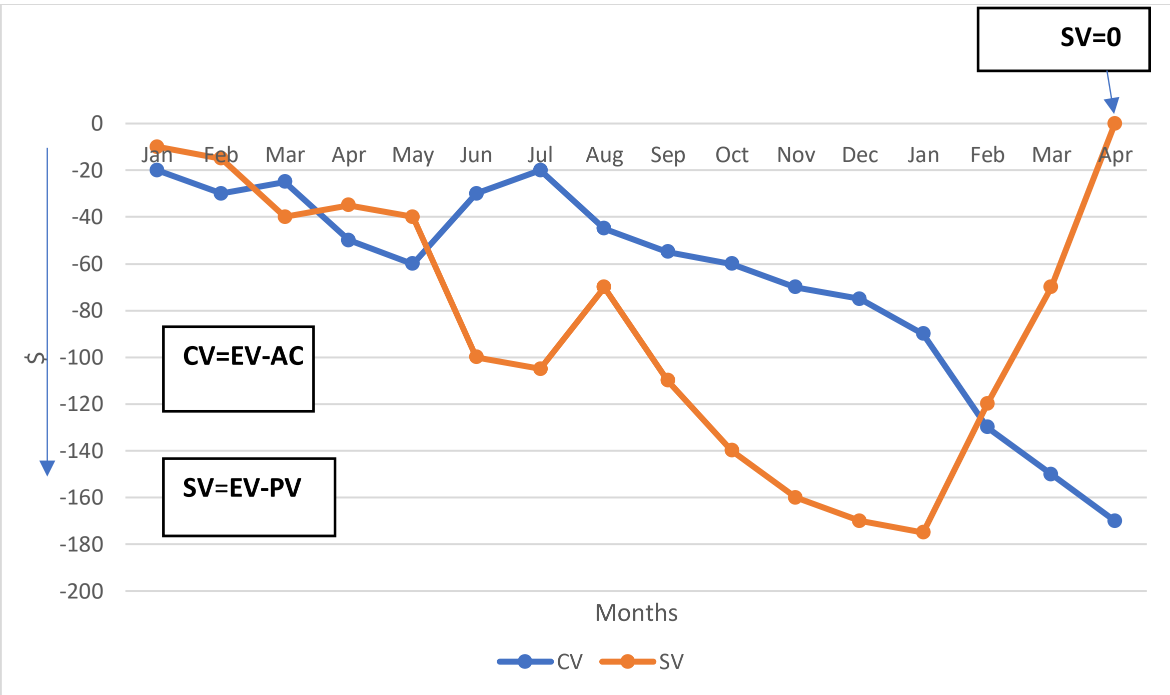
The limitation of the EVM schedule indicators that is consistent across the literature relates to the structural behavior of the measure as the project nears its end. The consensus in the literature is reflected in the observation made by (Lipke, 2012), which establishes, theoretically and empirically, that the EVM schedule indicators (SV($) and SPI($)), as opposed to cost measures, exhibit significantly different behavior towards the end of the project. The latter remain analytical throughout the project lifecycle, whereas the schedule indicators become structurally limited to zero variance and 1.0 index value as the earned value approaches the budget at completion, irrespective of the timely execution of the project or its delay as illustrated in Figure 2.

In addition to the challenge posed by SPI($) and SV($) convergence, there are several methodological problems that exist with EVM as a scheduling tool. According to (Ballesteros-Pérez & Elamrousy, 2018), EVM tends to create optimistic schedules in complex multi-path projects, since it ignores the variability in activity durations and the bias at merge points two features common to complex EPC projects. Furthermore, (Ballesteros-Pérez & Elamrousy, 2018) argue that EVM does not assess the completion of scheduled activities in the proper order, potentially leading to misinterpretations of the true progress of projects. These issues are particularly relevant in construction and EPC projects since they are undertaken under highly uncertain circumstances characterized by outdoors operations, project uniqueness, team uncertainty, and scope changes all factors that expose them to schedule risks much more than projects carried out in predictable industrial settings.

As (Henderson, 2003) explains, this phenomenon is caused by no schedule improvement whatsoever, but is simply due to the nature of the Earned Value Management system of calculations, whereby SV($) and SPI($) are calculated against the planned value curve rather than an independent time axis. (Lipke, 2012) further clarifies that with the earned value curve reaching its intersection with BAC, the difference between EV and PV shrinks, thus resulting in schedule performance indicators converging to their neutral values regardless of the amount of delay that continues to accumulate as shown in Figure 3. It is precisely because of this inherent flaw in the EVM system that it has long been considered much more reliable for calculating costs than schedules. As (Corovic, 2006) argues, the problem under discussion is what motivated the creation of the Earned Schedule concept.

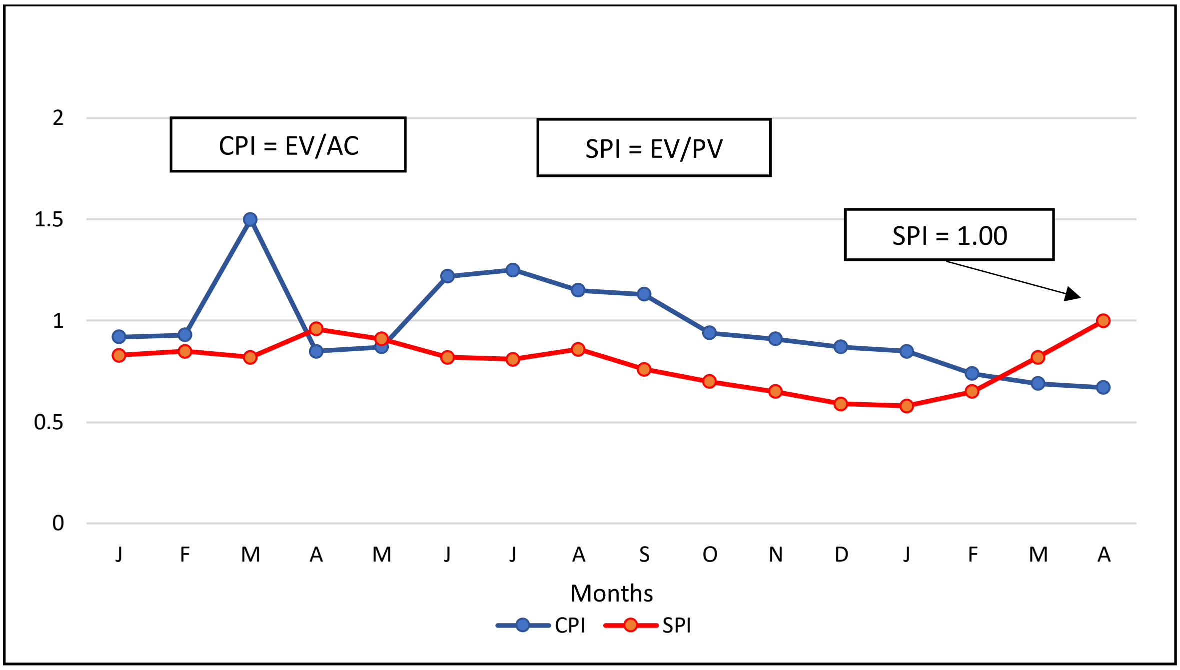
Although EVM has become a proven means of measuring performance with regards to cost and schedule, recent literature has highlighted the inherent inadequacies of EVM as a forecasting technique. According to (Agumalu, 2022), traditional EVM fails to provide the necessary forecasting capability to accurately predict future variances with respect to both cost and schedule in project settings. Traditional EVM acts essentially as a reactive measurement tool instead of being an active predictor due to which it falls short when it comes to forecasting performance in large-scale projects.

Figure 2: Evm Cost and Schedule Variances



Source : Elaborated by Authors, adapted from (Lipke, 2012)

Figure 3: EVM Cost & Schedule Performance Index



Source : Elaborated by Authors, adapted from (Lipke, 2012)

5 The Earned Schedule Approach: Time-Based Performance Measurement

The ES approach introduces a time-based framework that redefines how schedule performance is measured, replacing cost-denominated metrics with time-equivalent indicators anchored to the project's actual progress timeline.

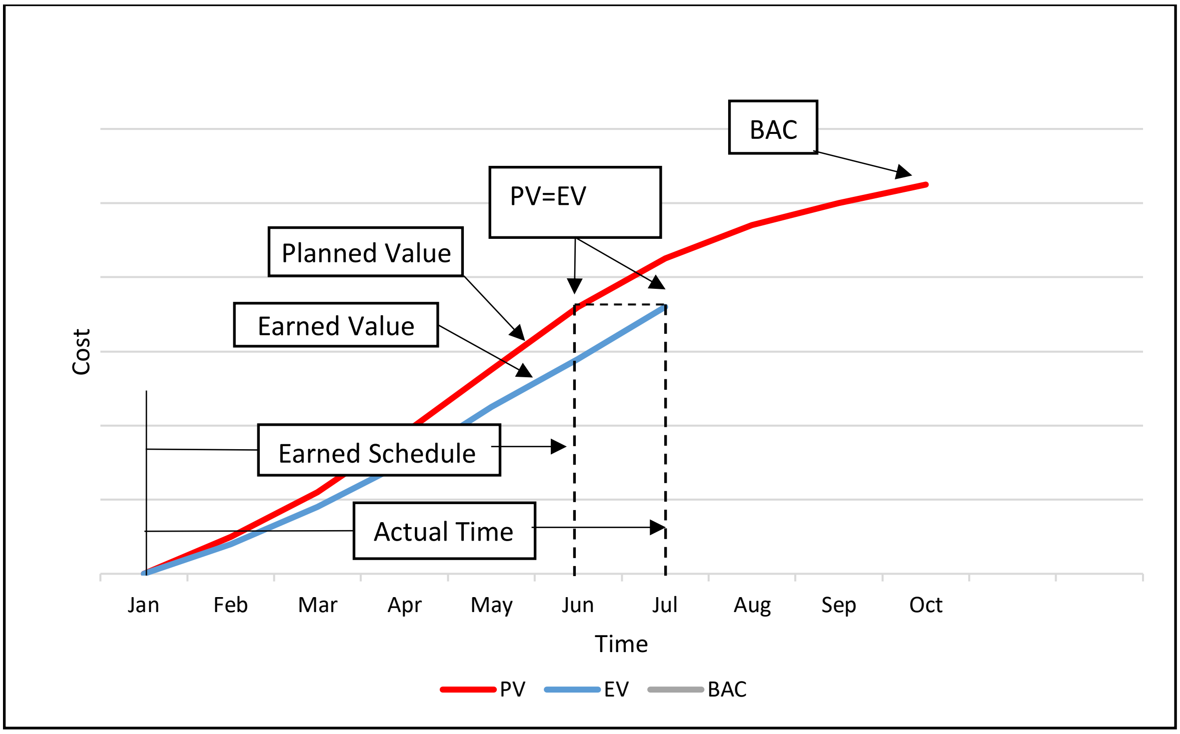
5.1 Underlying Concepts and Key Metrics

The ES approach was first proposed by (Lipke, 2003) as a time-oriented modification of EVM, which aims to overcome the intrinsic weakness of cost-based schedule metrics through shifting the focus of schedule performance measurement to time units instead of monetary units. The core concept behind ES according to (Lipke, 2012) revolves around identifying the position along the S-curve that corresponds to the level of earned value achieved at any particular moment in the project, thus enabling the transformation of the progress of the project into its time-equivalent form. Such a calculation leads to the determination of the ES metric measured in time units, which becomes the basis for calculating other ES metrics.

As (Lipke, 2012) defines, the two main metrics used to evaluate the effectiveness of the ES approach are Schedule Variance $SV(t) = ES - AT$ and Schedule Performance Index SPI(t) =

ES/AT, where AT denotes the actual time spent by the project at the reporting time. (Vandevoorde & Vanhoucke, 2006) explain that the Schedule Variance and Schedule Performance Index allow making an assessment of whether the project's schedule is in advance or delayed compared to the earned schedule using the time perspective in analogy to cost-based EVM metrics, although unlike SV($) and SPI($), these metrics do not converge mathematically. (Henderson, 2003) further highlights that one key finding from the literature regarding the Schedule Performance Index is that SPI(t), because it uses time rather than accumulated costs as a benchmark, maintains its diagnostic potential throughout the entire course of the project and does not become insensitive to schedule slippage near project completion.

Figure 4: Earned Schedule Concept

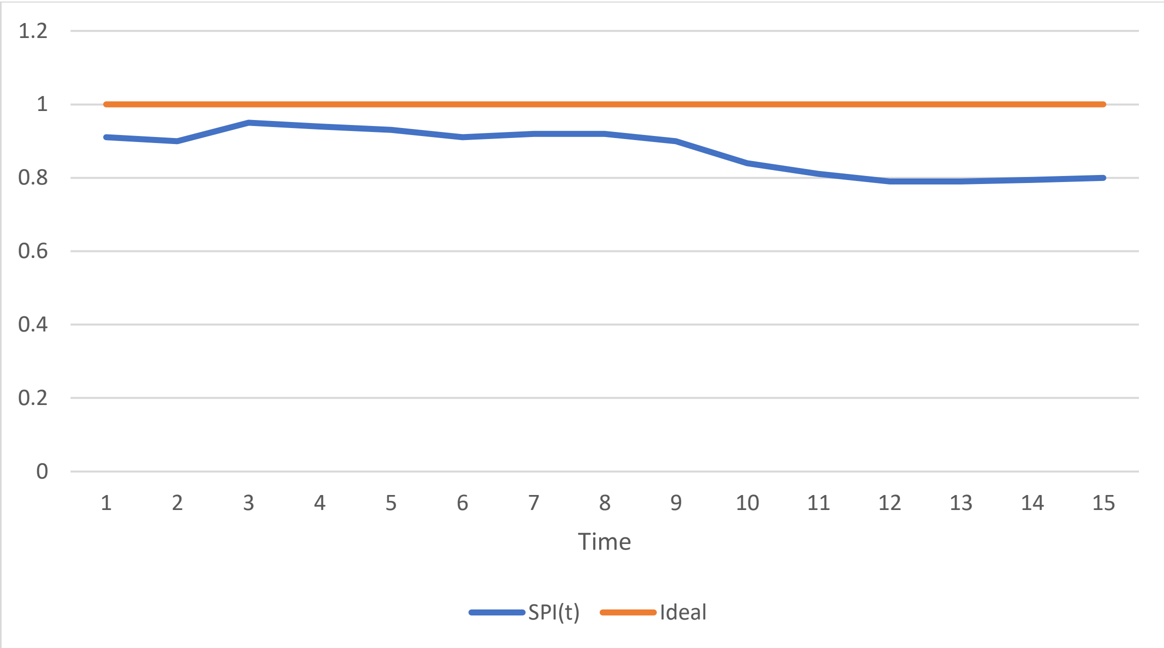


Source : Elaborated by Authors, adapted from (Lipke, 2012)

5.2 SPI(t) Behavior on Delayed Projects

An empirical example of how the behavior of SPI($) is different from the behavior of SPI(t) is provided by (Bruchey, 2012a). Specifically, the study examines a fictional acquisition program that takes 15 months to complete when originally planned for 12 months. In that regard, the analysis shows that despite being convergent to 1.0 while approaching the time point of reaching the BCWS, indicating the illusion of the recovery of the schedule, SPI(t) will stay under 1.0 over the whole period and will show poor scheduling over the whole project period and even after the initial expected finish of the project. Thus, one can conclude that the key difference in the behavior of the performance indices EVM and ES can be explained by their temporal basis. It should be noted that the results found by (Bruchey, 2012a) are corroborated by the empirical evidence available in the literature.

Figure 5: SPI(t) for late completing program



Source : Elaborated by Authors, adapted from (Bruchey, 2012a)

5.3 Duration Forecasting Using IEAC(ES)

Similar to the cost-based models, the ES model also has its own duration forecasting equation that can be expressed by the following equation, referred to as the Independent Estimate at Completion for schedule:

$$IEAC(ES) = \frac{PD}{SPI(t)}$$

where PD represents the planned duration of the project (Lipke, 2009). As opposed to the other two equations used for deriving forecasted values, i.e., the IEAC(PV) and IEAC(EV), this equation only uses time-based information in the form of schedule efficiency index and is independent of the impact of any cost performance distortions on its accuracy. As (Bruchey, 2012a) demonstrated through a simulation analysis conducted in The Measurable News magazine, the ES duration forecasting methods outperformed the cost-based methods throughout the project's three life-cycle phases (early, middle, and late) on average.

5.4 Earned Schedule Forecasting Reliability

Earned Schedule forecasting reliability was assessed based on empirical comparisons with actual project data. According to (Lipke, 2017), duration forecasts for 16 projects were made via comparison of the SPI(t)-forecast approach and the unit performance factor (PF) = 1 assumptions. It turned out that PF=1 was inferior to other approaches in just four out of 16 cases, proving the superior forecasting quality of PF=1 approach. Nevertheless, it was shown by (Lipke, 2017) that statistical forecasting based on PF=1 assumptions provides unreliable and overly optimistic confidence intervals, thus making it unsuitable for proper project control practice. In addition, for projects containing downtime or stop-work periods, it was found that only the approaches taking such situations into account provided proper forecasting results in the form of reasonable estimates. At the same time, other approaches that did not do so were characterized by excessive volatility or consistent optimism. Overall, this highlights the necessity to carefully analyze actual project data when using Earned Schedule forecasting approaches.

In empirical research on the forecasting accuracy of the ES approach, (Lipke, 2015) utilized data from sixteen actual projects. For forecasting accuracy purposes, (Lipke, 2015) categorized the SPI(t) and Remaining Duration (RD) values in nine scenarios and divided them into three categories: true, misleading, and false forecasts at ten percent progress intervals. Overall, the findings indicated that there was an increasing trend in forecasting accuracy as the project progressed; in particular, there was a marked increase in the true category and a decrease in misleading and false forecasting throughout the entire project lifespan. (Lipke, 2015) further established that in case a ten percent forecasting tolerance level is set, the percentage of true forecasts rises considerably, and ES forecasting was evaluated to be satisfactory to very satisfactory for 95 percent of the project period. Based on these findings, (Lipke, 2015) concludes that project managers working under EVM management should confidently rely on the duration forecasts obtained using the ES approach. ES duration forecasting has greater reliability and consistency compared to other cost-based EVM duration forecasting techniques.

6 Synthesis and Research Gaps

The body of literature examined in this chapter together provides a convincing theoretical foundation for this study. With the development of project management into a recognized academic field, substantial knowledge has been generated on performance measurement, with EVM being the most popularly used integrated method. The data proves that EVM is an efficient tool for cost measurement in various projects, including construction and EPC projects. But there is one critical aspect of performance measurement where a significant deficiency persists, that is, schedule performance measurement, wherein the intrinsic mathematical constraint of EVM schedule measures, as recognized by (Lipke, 2012), and later supported by numerous studies, makes them increasingly unreliable towards the end of project implementation.

Earned Schedule technique bridges this research gap by incorporating time-based metrics that maintain their diagnostic power across all stages of the project life cycle, as well as offering a more reliable foundation for duration prediction. Although there are several valuable aspects to the Earned Schedule framework, the available empirical literature still suffers from a lack of research focused on the application of this methodology in authentic environments of EPC projects, with no research having been conducted to compare the performance of EVM versus ES metrics using lifecycle data for EPC projects within the Algerian industry.

The tables below give an overview of the studies selected and considered to be highly relevant to the present study, describing their significant features in connection with the present study.

Table 2: Overview of Studies Most Aligned with the Present Investigation

Study	**METHODOLOGY**	**Key Findings**	**Limitations**
Bruchey, W. J. (2012).	Quantitative; EVM/ES metrics computed on 4 DoD CMA programs using MSE and percent difference analysis via spreadsheet	ES metrics (in particular, IEAC(t)ES) yielded better forecasting accuracy than EV metrics throughout the entire span of four DoD acquisition projects, resulting in closer forecasts to	ES measures gave false alarms for all four programs that there was a breach of schedule, which could have led to unnecessary corrective actions or even the cancellation of the programs. The research is confined to acquisition programs of the DoD, which

Study	METHODOLOGY	Key Findings	Limitations
		their actual completion durations according to the MSE and percentage difference analyses. The ES metric alone exhibited clear benefits for project monitoring and control purposes.	means that its results cannot be generalized to projects operating under different conditions. Moreover, ES procedures proved to be inaccurate enough to be used independently as management techniques for programs.
Lipke, W. (2009).	Quantitative, rankings of 5 forecasting methods across 16 projects at 7 completion ranges	At all seven percent levels of task completion analyzed, ES always provided more accurate forecasting than any of the four alternative models using EVM techniques based on standard deviation from actual time taken for the task. Therefore, it is established beyond doubt that the null hypothesis that EVM offered better forecasting accuracy	There was an issue of data adequacy in this study, with a sample size of just sixteen projects. Moreover, all of the projects studied belonged to the domain of high technology and IT, hence limiting the applicability of the results obtained in other delivery models, for example, the EPC industrial construction model.

Study	METHODOLOGY	Key Findings	Limitations
		is false at all completion levels.	
Vandevoorde, S., & Vanhoucke, M. (2006).	Quantitative; comparative analysis of 3 forecasting methods applied to 1 fictive project and 3 real-life projects from a single Belgian company across linear and non-linear progress scenarios	It can be argued that ES forecasting technique was the only technique that provided dependable results during the whole process of the project life cycle, especially during the last stages of project implementation and for projects that do not have linear progress. The authors suggest adopting the ES approach to late project control.	However, the actualization process is restricted in the sense that it involved only three projects from one company in Belgium. The present study does not deal with EPC or heavy industrial construction sites.

Source: Elaborated by the Authors

Chapter's conclusion:

With regard to the theoretical basis for this research, the review that is carried out in this chapter has provided the required theoretical framework needed for this study. While EVM is undoubtedly the main paradigm used in the integrated evaluation of project performance, it is clear from the theoretical literature that there are structural shortcomings associated with EVM when it is considered as a means of measuring project schedule performance. In this case, the Earned Schedule paradigm stands out as a theoretically sound option.

CHAPTER 2: METHODOLOGICAL FRAMEWORK

Introduction of Chapter 2:

The current chapter sheds light on the methodological framework used during the empirical investigation comparing traditional EVM indicators with time-based indicators of ES approach in three EPC projects of SARPI. The current chapter can be divided into five parts. First, there is a presentation of the host organization, namely SARPI. In other words, SARPI's background, organizational structure and activities are discussed as the real-world environment for this research. Second, an overview of the data sources and performance data used in this study is presented. Third, a qualitative part includes conducting semi-structured interviews with some experts from SARPI and establishing grounds for this study. Fourth, the calculation model is described in detail, presenting all the formulas of EVM and ES used for calculating indicators being compared. Finally, three analytical methods will be presented, which will be applied for assessing forecasting accuracy and diagnostic ability of cost-based and time-based schedule indicators.

1 Presentation of the Host Institution SARPI

In this chapter, we seek to present a comprehensive overview of SARPI, the Algerian company for the realization of industrial projects La Société Algérienne de Realisation de Projets Industriels.

1.1 Definition of SARPI Institution

(Information and documents provided by the institution)

The Algerian company for the execution of industrial projects SARPI is a joint-stock company established in June 1992, in partnership between SONATRACH (Algeria) and ABB SPA (Italy).

In March 2018, ABB shares were acquired by SIP – SH holding company after the end of the partnership and ABB's decision to sell the EPC activity to a third party.

SARPI Spa is fully owned by SONATRACH SERVICES PARA PETROLIERS (SSPP) holding company.

SARPI carries out its activities in the execution of industrial facilities, particularly in the energy sectors (oil and gas, renewable energies, water…).

SARPI has a strategic and wide geographical area that enables it to effectively intervene in its projects and be close to its clients.

The headquarters of SARPI is located in Hydra municipality, Algiers province, in addition to the headquarters, SARPI has three (03) regional directorates:

- Regional directorate in Hassi R'mel (DR HRM).
- Regional directorate in Hassi Messaoud (DR HMD).
- Western regional directorate (DR OUEST).

It also has two (02) regional directorates currently installed:

- Regional directorate in In Amenas (DRIA).
- Regional directorate in Adrar (DRAD).

1.2 Main Clients of the Institution

The following are the main clients of SARPI SPA:

- SONATRACH
- SONELGAZ
- JV GAS (SONATRACH – BP et EQUINOR)
- Berkine Group (SONATRACH – ANADARCO)
- Samsung CT
- METKA
- SONAHES

Figure 6: Sarpi's clients

Source: Information and documents provided by the company

1.3 Activities of the Institution

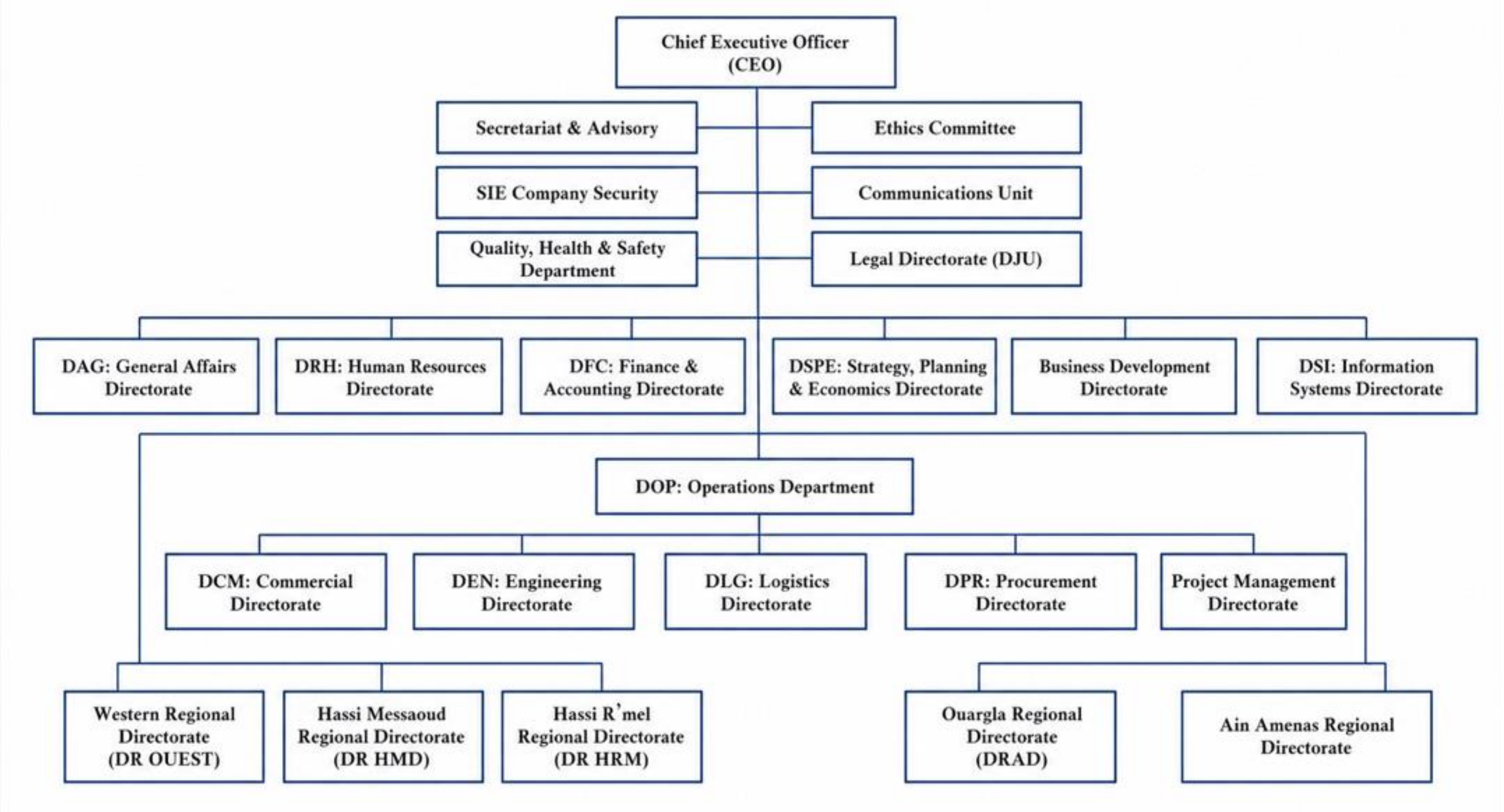
SARPI operates in the oil, gas, and energy sectors; it specializes in:

- Execution of pumping stations and oil and gas treatment units.
- Rehabilitation of pipelines (gas and oil pipelines).

- Execution and upgrading of compression stations, pumping stations, and gas processing plants, and so on.
- Execution of central pipeline facilities (terminal stations, cut-off stations, and separation stations).
- Maintenance of industrial facilities in the oil, gas, and energy sectors.
- Execution of electrical stations and industrial facilities in the energy sector.
- Installation and rehabilitation of tanks.
- Supply and subcontracting operations.
- Full service and industrial maintenance.
- Basic and detailed engineering.
- Logistic support.

SARPI provides a wide range of services mainly including engineering (design), procurement, construction, installation, and pre-commissioning/commissioning, moreover, SARPI participates in the execution of major new high-level projects such as seawater desalination plants.

Figure 7: Sarpi's organizational chart



Source: Information and documents provided by the company

1.4 Revenues and Expenses Related to the Activity of the Institution

Operationally, SARPI's activities, turnover, and expenses are structured across three distinct EPC components, each tracked separately for financial and managerial purposes.

1.4.1 Activity of the Institution

The institution is an economic company specialized in the execution of industrial projects particularly in the energy sectors (oil and gas, renewable energies, water…). It is also considered that SARPI is currently a reference institution in the field of project execution with the EPC model, and the seawater desalination project in El Tarf is considered one of the most important projects of the institution currently, therefore we will take it as a reference in the examples to explain how the institution works.

ENGERNING:

Where the institution carries out engineering studies of projects such as: design and planning of infrastructure, design of hydraulic and electrical systems, evaluation of available desalination technologies...

PRUCREMENT:

The procurement process differs from one project to another according to project needs on one hand and the contract agreed upon in the project on the other hand, for example, the construction process of the desalination plant in El Tarf requires:

- Desalination and filtration equipment
- Pumping and storage equipment
- Testing and measurement equipment
- Chemical materials

The project contract stipulates that SARPI is responsible for supplying part of the materials mentioned previously, while another institution is responsible for supplying the other part.

CONSTRUCTION:

It carries out construction operations such as building the desalination plant, building and repairing infrastructure...

To understand the activity of the institution, it is necessary to know the following points:

- The institution does not always take projects entirely alone (EPC), this depends on the agreement, it may be responsible for construction while other companies are responsible for procurement and engineering, or it may be responsible for procurement and construction only.

- The institution may be responsible for part of the procurement while another is responsible for the second part.
- The institution separates turnover and expenses for each activity separately.

1.4.2 Turnover of the Institution

Turnover is divided into three sections:

Engineering Turnover:

Receipts in exchange for the execution and delivery of an engineering study according to the agreement concluded in advance, for example: in January, the institution receives its receipts in exchange for delivering the engineering study related to the design of the electrical and hydraulic system.

Procurement Turnover:

Company receipts in exchange for supplying the agreed equipment, procurement fees (procurement expenses plus a profit margin), receipt delivery is according to prior agreement either by setting payment dates or payment upon delivery of equipment.

Construction Turnover:

Company receipts in exchange for construction operations, receipt delivery is according to prior agreement either by dividing payments into specific periods (monthly, quarterly, annually, or dates specified in the contract), or dividing payments according to the completion of specific operations.

1.4.3 Institution Expenses

They are divided into four sections:

Engineering Expenses:

Company expenses during the engineering process (including labor expenses dedicated to engineering, services, rent, purchase...)

Procurement Expenses:

Company expenses during the procurement process (including labor expenses dedicated to procurement, services, rent, purchase...), in addition to equipment acquisition and import expenses (purchase, transport...), taxes (VAT, customs duties..)

Construction Expenses:

They are considered the most important for the institution as they represent the largest percentage of total expenses, therefore they are studied in more detail:

- Labor: represents wages of workers in project construction, contributions paid to social organizations...

- Purchase: tools and manual equipment, safety equipment such as helmets and gloves, equipment and maintenance.
- Rent: expenses of renting equipment used in projects, renting buildings...
- Catering services: expenses of feeding workers in construction.
- Services: other service expenses (general contracting, maintenance and repairs, transport of workers...)
- Other expenses: expenses related to the management of general and regional administrations.

Section Three: The Host Administration

2 Methodological framework of the research

The research methodology for this study involves a combination of qualitative and quantitative methods. We began with the qualitative interviews because the research problem was first identified in practice: we needed to understand how project-control professionals at SARPI actually use EVM, what limitations they experience, and whether Earned Schedule was already known or considered useful. This exploratory step was necessary to ground the study in the organizational context and to refine the analytical focus before testing anything quantitatively. We then moved to the quantitative phase to objectively measure and compare the diagnostic and forecasting performance of EVM and Earned Schedule on real completed EPC project data. Using both methods was essential because the interviews provided context, explanation, and problem formulation, while the quantitative tests provided empirical verification and comparison; together, they allowed the study to move from practical observation to evidence-based validation.

2.1 Data Source:

It is within the framework of the Department of Strategy, Planning, and Economy of SARPI that project performance records for all important EPC contracts managed by SARPI are stored. During this internship as a part of this dissertation, access was provided to performance information of three big EPC projects undertaken by the company. Apart from the quantitative data collected, there was also direct contact with important professionals at SARPI, enabling the researcher to conduct semi-structured interviews. These interviews gave more insights into the monitoring and management of projects at SARPI.

Performance records for each project include three main parameters: the Budget at Completion (BAC) the total contract budget approved for completion of the whole project; the planned completion rate – a schedule showing the expected progress of works expressed in percentages for each reporting period; the actual completion rate – an indicator showing the real progress in percentage for each reporting period. In addition, the Actual Cost (AC) for each period was provided. The three variables listed above are BAC, planned and actual completion rates, and AC. These data items form the main inputs used to calculate all indicators associated with the Earned Value Management and Earned Schedule techniques that were employed in our investigation. In particular, the Planned Value (PV) and the Earned Value (EV) are obtained by multiplying the BAC by planned and actual completion rates, respectively. Subsequently, the values obtained are further used to obtain a number of cost and schedule management indicators, including such indicators as CV, SV($), CPI, SPI($), SV(t), SPI(t), and IEAC(EV), IEAC(PV), IEAC(ES).

2.2 Semi-Structured Interviews

Besides the statistical analysis, Semi-structured interviews have been conducted with leading experts of SARPI in order to build the necessary basis for the research in question. In particular, this set of interviews includes four interviews that were conducted with leaders of the DSPE unit and one other interview with another expert representing the DPM unit. The objective of this interview is to find out the existing practice of project management at SARPI, the presence of EVM at SARPI, ways of forecasting in terms of project time and cost management, as well as advantages and disadvantages of this strategy.

The selection of this interviewing technique was done deliberately in order to give flexibility to the conversation regarding the experiences of the respondents in monitoring projects, their perspective on modern methodological practices involved in this process, as well as their attitude to using advanced scheduling strategies in project monitoring. The chosen form of the interview helped ensure the inclusion of various expert perspectives, although it was focused on discussing key areas of investigation. The collected data obtained with the help of qualitative research adds context to the empirical data collected by the study.

2.2.1 Selection of Interviewees

In our study on the evaluation of project performance monitoring practices at SARPI, four semi-structured interviews were conducted with key professionals from the project control and planning functions. The individuals were selected on the basis of their significant contribution to the execution and oversight of project budgets, schedule control, and strategic planning within the organization. The profiles of the interviewees are presented below:

Table 3: Profile of the interviewed experts and their respective departments

Expert	**Position Held**	**Department**	**Date of Interview**	**Interview duration**
Expert 1	Budget and Management Control Engineer	DSPE – Direction of Strategy, Planning & Economy	May 4, 2026	40 Minutes
Expert 2	Head of Budget and Management Control	DSPE – Direction of Strategy, Planning & Economy	May 4, 2026	30 Minutes
Expert 3	Planning Manager & Project Control	DPM – Direction of Project Management	May 4, 2026	50 Minutes
Expert 4	Director of the Direction of Strategy, Planning, and Economy	DSPE – Direction of Strategy, Planning & Economy	May 6, 2026	45 Minutes

Source: Elaborated by Authors

2.2.2 Selection Criteria of the Interviewed Experts

In the context of the present research, four experts from the Direction of Strategy, Planning, and Economy (DSPE) and the Direction of Project Management (DPM) of SARPI were interviewed. The criteria that were considered while choosing these individuals included their actual participation in project cost and schedule control activities, responsibilities performed by them in relation to the functioning of SARPI, as well as practical knowledge of monitoring techniques used in EPC projects.

Expert 1 – Budget and Management Control Engineer, DSPE

This individual was chosen to participate in the research due to their active participation in the budgeting process and daily monitoring of budget deviations. Being in charge of project budgets, this individual could contribute to the research with insights on how project costs are being tracked and reported in practice. In addition, personal experiences with monitoring instruments helped reveal possible limitations of existing approaches.

Expert 2 – Head of Budget and Management Control, DSPE

As an expert who supervises all budget control processes in the organization, Expert 2 was identified as a key informant in this study because he has an overall idea about the methods used for cost management and the power to verify these processes. The opinions of Expert 2 were significant since they helped in comprehending the approach to project financial control and how the performance measurement system is structured in SARPI.

Expert 3 – Planning Manager & Project Control, DPM

As an expert in planning and control process, Expert 3 was identified as a key informant since his work is highly related to the core topic of the research. Expert 3 works in the Direction of Project Management as a planner of projects, and in addition to that, he has a responsibility for implementing project control activities and using various planning tools. Therefore, his opinion was important in determining whether EVM techniques are being applied during the evaluation of schedules in SARPI.

Expert 4 – Director of Direction of Strategy, Planning, and Economy (DSPE)

This expert was selected based on his expertise related to strategies and institutions, since he was the highest respondent in terms of position among all the other experts. The function of this expert was that of overseeing all aspects of governance relating to planning, budgeting, and economics for all projects within SARPI. This was crucial in putting the existing approaches in context with regard to strategy and institutional constraints and opportunities associated with EVM adoption.

2.2.3 Thematic Analysis Procedure:

Thematic analysis was carried out through analyzing the transcripts of the interview answers and noting down the common occurrences with regard to the following three major themes: the present state of project performance monitoring processes in SARPI, the level of awareness and use of EVM methodology, and the limitations of schedule control mechanisms. These themes were based on commonalities noted in the four interviews and helped validate the quantitative results discussed in this study.

2.3 EVM and ES Indicator Calculation Framework

For all three EPC projects, the calculated values of Planned Value (PV) and Earned Value (EV) at each period were used to determine the corresponding performance indexes concerning schedule and cost performance. The formulas for calculating traditional EVM performance indexes have already been given in the literature, while the equations used in this paper are shown below.

Planned Value and Earned Value are calculated based on the BAC and actual completion rate as follows:

$$PV = Planned\ Completion\ Rate \times BAC$$

The Schedule Variance shows the deviation between the value of work completed and the value of work planned:

$$SV(\$) = EV - PV$$

The Schedule Performance Index shows schedule efficiency regarding cost performance:

$$SPI(\$) = \frac{PV}{EV}$$

The Earned Schedule equals the equivalent time to reach a certain level of project completion based on the Earned Value (it can be seen as a point of intersection on the PV curve). The calculation equation is given below:

$$ES = n + \frac{EV - PV_n}{PV_{n+1} - PV_n}$$

where n is the number of completed periods when cumulative PV<=current EV; PV_(n+1) is the planned value of the next period.

Schedule Variance (expressed in time units):

$$SV(t) = ES - AT$$

where AT = Actual Time, AT represents the actual time taken during the reporting period.

Schedule Performance Index (time-based) calculates the efficiency of the schedule in terms of time:

$$SPI(t) = \frac{AT}{ES}$$

Similar to conventional EVM ratios, a negative SV(t) means that the project is delayed, and an SPI(t) less than 1.0 implies poor schedule performance.

IEAC(PV) Using the average work rate planned:

$$IEAC(PV) = AT + \frac{BAC - EV}{PV_{av}} \textit{where } PV_{av} = \frac{PV_{cum}}{n}$$

Calculates the ultimate time period that will be required to complete the project, using the average work rate planned to be used for completing the remaining work, regardless of actual performance.

IEAC(EV) Using the average work rate earned:

$$IEAC(EV) = AT + \frac{BAC - EV}{EV_{av}} \text{where } EV_{av} = \frac{EV_{cum}}{n}$$

Calculates the ultimate time period that will be required to complete the project, using the average work rate that has been earned up to this point, based on actual performance.

IEAC(ES) based on the Earned Schedule time-based performance index:

$$IEAC(ES) = \frac{PD}{SPI(t)}$$

where PD is the planned duration of the project.

Predicts the total duration of the project with the use of the schedule efficiency index that operates on the time scale only, and not on cost efficiency.

In each of the three formulas presented above, AT is the actual time spent, n is the number of time periods in which the results were gathered, and BAC stands for Budget at Completion. In addition, when the value of IEAC is higher than PD, it means that the project will be completed late.

This formula measures the difference between the forecasted and actual final duration at every reporting period during the entire life cycle of the project. Thus, this approach allows comparing forecasting techniques by their degree of forecasting accuracy. A small percent difference means that the forecasted final duration of the project is quite close to the real one. On the contrary, large percent difference indicates high forecasting errors. The formula below was applied to each IEAC forecasting technique at every reporting period:

$$\text{Percent Difference} = \frac{IEAC(t) - FD}{FD} \times 100$$

IEAC(t) stands for the forecasted final duration generated by a particular forecasting technique at a particular reporting period, and FD refers to the real final duration of the project at the moment of its completion. The above-mentioned time-based ratios are used together with the cost-based ratios for the three analysis tests discussed in the subsequent section.

2.4 Analytical Tests:

Three successive analytical tests are conducted, each targeting a distinct dimension of schedule performance measurement and forecasting accuracy across the three EPC projects.

2.4.1 Test 1: Study of SPI(t) and SPI($) Below 0.90 Through Time

Test One is formulated for evaluating and comparing the dynamics of SPI(t) and SPI($) throughout the entire time period for each of the three EPC projects. To accomplish this task, both SPIs are estimated at each reporting interval according to the formula described above and presented on the graph with reporting period and SPI being placed along the X- and Y-axes respectively. A reference point equal to 0.90 is chosen as a point of reference as any SPI lower than this point can be regarded as significant schedule delay. Both SPIs are plotted on one graph to provide an opportunity to compare them visually throughout the whole time period.

This analysis is conducted separately for each of the three EPC projects, thus yielding three graphs in total. Then these results are summed up in the form of the fourth graph demonstrating the average dynamics of both SPIs in all three EPC projects.

2.4.2 Test 2: Evaluation of the Divergence between SV(t) and SV($)

The second test will focus on the dependence of the two indicators of variance in schedules, SV($), which is measured in monetary terms, and SV(t), measured in time terms, and more importantly, on how this dependence changes as the project progresses. Both of these indices are calculated at the end of every reporting period, for all the three projects, with the help of the equations formulated in the above section. The fact that the two indices are calculated on entirely different parameters makes their display on one chart difficult. Hence, to compare them effectively, two vertical axes are used with one representing SV($) and the other, SV(t).

What becomes the key question that this test tries to answer is the stage in the lifecycle of the project when these two variables start diverging from one another. In order to do this, the trends of both these variables need to be determined throughout all the stages of reporting. The point where the SV($), having been negative, begins its recovery towards zero, while

SV(t) keeps going down, is considered to be the divergence point. This approach needs to be taken for each of the projects individually, with the results being averaged together into one graphic.

2.4.3 Test 3: Forecasting Accuracy Comparison

Finally, the third test involves assessing the precision of the predictions about the actual final duration made by the three duration forecasting techniques, that is, IEAC(EV), IEAC(PV), and IEAC(ES). Specifically, for each reporting period in each project, the forecasted durations resulting from each duration forecasting method are calculated based on the previously provided equations and then compared to the known final duration of each project by using the percent difference formula.

Three graphs per project will be created plotting the percent differences obtained in this way for each of the three IEAC curves. That is, three curves corresponding to each of the three forecasting techniques will be put on one chart per project to visually analyze how close the forecasted final duration was in each case to the actual final duration of each project. Three graphs will be plotted for each project resulting in four graphs when combined in an averaged figure summarizing all three projects. The third test does not aim at the assessment of projects; instead, it focuses on comparing forecasting techniques.

Chapter's conclution:

The current chapter provides an overview of the methodology implemented for conducting empirical research within the framework of this study. The primary data for the analyses performed were three datasets regarding EPC projects obtained from SARPI; using those datasets, all the PV, EV, AC, and EVM/ES performance measures (defined by formulas provided above) were calculated. In order to ensure the qualitative aspect of the research, semi-structured interviews were held with four SARPI specialists of DSPE and DPM directions. Those interviews helped to gain insight into the application of EVM principles and the problems associated with it. The following step included three different analyses conducted for each project separately. The first analysis was devoted to the comparison of SPI(t) and SPI($) dynamics, the second analysis to determining the point of deviation of SV(t) from SV($), and the last analysis was about forecasting efficiency of IEAC(EV), IEAC(PV), and IEAC(ES).

CHAPTER 3: RESULTS AND DISCUSSION

Introduction of chapter 3:

This chapter offers a presentation and discussion of the results of the empirical analysis conducted based on the use of the two interrelated methods used in this study. This chapter consists of two major parts. First, the results of the empirical investigation are discussed. In particular, this section presents the qualitative findings resulting from the thematic analysis of the four semi-structured interviews that were conducted with the SARPI project control specialists, and the quantitative findings obtained through application of the Earned Schedule approach to three case study projects implemented within the EPC framework. Second, an analysis of the relationship between these findings is offered. Namely, this section discusses the level to which the field evidence supports the theoretical problems associated with traditional EVM schedule indicators and adds to the validity of the Earned Schedule as a better alternative forecasting technique for EPC projects.

Overall, these two parts serve as the means to provide an empirical solution to the research problem identified in the previous chapters.

1 Results:

The findings from the empirical study will be presented in this section in two different parts, namely the themes drawn from the interview sessions conducted using the semi-structured format with SARPI experts, and secondly, the results from the case studies based on the Earned Schedule approach.

1.1 Thematic Analysis of Interview Findings

This next section includes a thematic analysis based on the answers provided by the interviewees from the four semi-structured interviews held at SARPI. This analysis includes three thematic axes where the questions are presented two to three at a time. For each question, a synthesis of the answers is provided based on what the respondents said, showing their points of agreement and disagreement and the findings resulting from the interviews.

Axis 1: Current practices of project control and forecasting.

Q1. According to the answers, it seems that both cost and schedule forecasting at SARPI is based upon experience and also structured approaches to estimating. Past experiences from previous projects are used as a point of reference, especially those that resemble current projects with respect to size and type. As far as the detailed process of estimation goes, the approach becomes more sophisticated, taking into account parametric ratios, WBS bottom-up costing, quotations analysis, and planning software like Primavera and SAP PS. An important point to take away is the fact that no structured cost referential is applied to the process of estimation. The deferral of one respondent to the Planning Manager further confirms that forecasting expertise remains concentrated at the operational level rather than uniformly distributed across all control functions.

Q2. It appears that there is a remarkable level of consensus among the respondents regarding the philosophy behind standardization and adjustment. In all responses where the methodology used was explained in substantive detail, the firm is said to function according to a certain standard framework based on the conventional structure for a work breakdown system, existing procedures, and templates that can be reused. However, this framework is subsequently adjusted to suit each individual project according to its particular characteristics, such as its nature, complexity, scale, geography, and level of risk. Human capital is another important variable because the proper use of this framework is contingent upon the knowledge and experience possessed by the project manager. That one respondent delegated responsibility for answering this question to the Planning Manager once again confirms the conclusion drawn in Q1 about the level of methodology expertise being vested in the operational planning level. The issue here is that the process of adapting a standard methodology does not involve a properly defined procedure, which could lead to inconsistencies in evaluating and reporting performance on projects of various kinds.

Axis 2: Application and Limitations of EVM in EPC Projects

Q3**.** The unanimous answer from the four participants is that EVM is indeed an officially recognized and practiced method of project control at SARPI, which has been consistently employed in all phases of projects, from planning until closeout. In addition, the consensus reached by all participants on this issue is important for its own sake, because it confirms that EVM is more than just a textbook concept; rather, it is a firmly established approach in organizational practice. Moreover, this also means that the research carried out here has practical relevance, as the limitations of EVM indicators to be discussed further on have actually been experienced.

Q4. It can be seen from all the four responses that there is no doubt that the entire range of EVM parameters including PV, EV, AC, CPI, SPI, and SV is always computed and incorporated into the company’s reporting system, right from its operations up to directorate-level decision making. This unanimity clearly indicates that EVM is being implemented in full measure within the company.

Q5: The answers given to the question at hand have shown a discerning criticism of the accuracy of traditional schedule indicators associated with the EVM system. Two out of the four respondents have provided answers based on a solid technical understanding of the limitations. The former mentions one of the most fundamental issues associated with the SPI($) and SV($) the issue of interpretability, since these indices are expressed using cost-related variables rather than time-based ones. Third respondent provides an answer based on a sound analytical understanding of the convergence limitation of SPI($) and SV($). In other words, both of these indices tend to approach their neutral values when the time goes by, giving false impressions about schedule recovery despite the delays. The two remaining answers, which show a deferral to the Planning Manager, only confirm the idea that people with knowledge about limitations work in close contact with the indicators under analysis.

Q6. The answers to this question have a strong consensus on one major limitation: the declining ability of classical EVM schedule measures to detect schedule deviations towards the end of the project. Three out of four interviewees, who hold different positions in their organizations, mention the tendency of SPI to gravitate towards 1 and SV towards 0 as the project nears completion despite major delays having been built up during the project's entire lifespan. The tendency to converge in this way makes the indicators misleading at the very time when they should be providing accurate feedback about the project's schedule progress. This creates an obvious need for a more sophisticated time-based technique like Earned Schedule. The observation that the limitation was consistently acknowledged by interviewees occupying various hierarchical levels and not prompted by academic input lends considerable empirical credibility to this conclusion.

Axis 3: Awareness & Adoption Potential of Earned Schedule (ES)

Q7. The four participants were unequivocal in stating their lack of familiarity with the Earned Schedule technique. In all organizational ranks, from the operational engineer to the directorate, ES has not been employed or mentioned in any way in relation to schedule management for the EPC project at SARPI.

Q8. The four participants were enthusiastic about the adoption of a new scheduling technique that would improve the accuracy of schedule forecasting for the entire span of EPC projects.

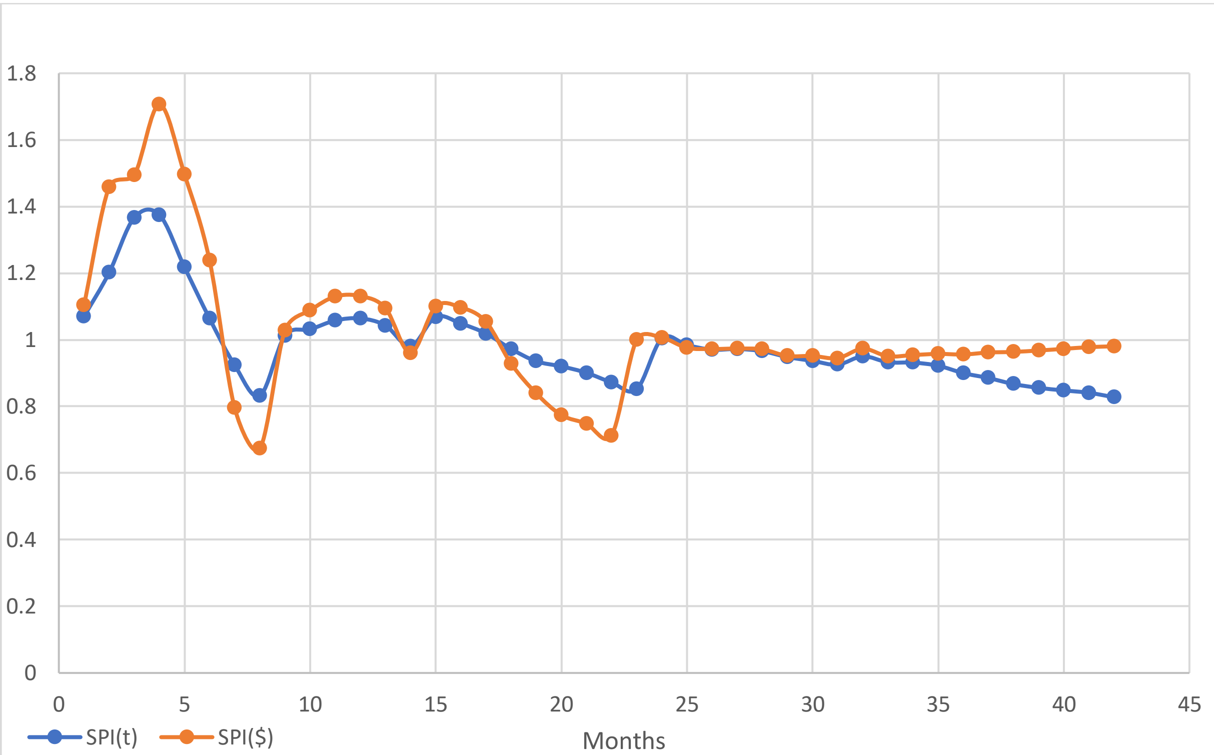
1.2 Case Study Analysis: Application of Earned Schedule to EPC Projects

This research uses the Earned Schedule method for analyzing the three actual EPC projects performed by SARPI, with an objective of empirically evaluating the performance and reliability of conventional EVM schedule metrics as well as their time-based equivalent earned schedule measures.

1.2.1 Test 1: Study of SPI(t) and SPI($) Below 0.90 Through Time

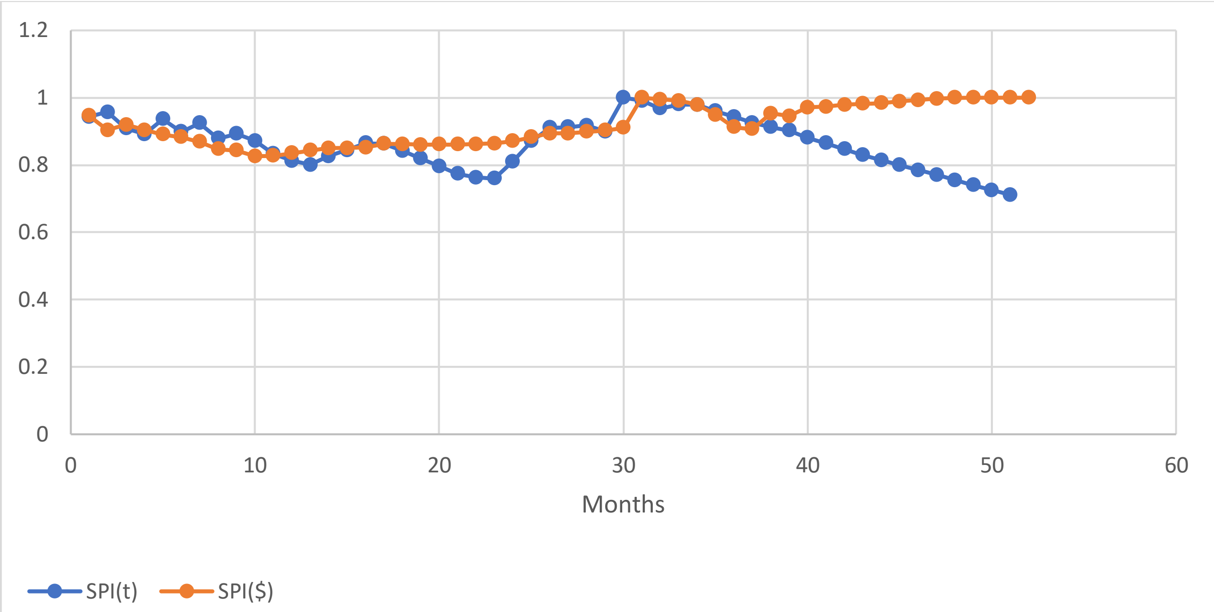
The first test aims to investigate the evolution of SPI(t) and SPI($) over the course of the projects. Previous studies suggest that SPI($) tends to converge toward 1.0 during the final stages of a project and thus becomes less informative in Earned-Value-Management. In this-research, the tests will be carried out on three projects, Project 1, Project 2 and Project 3. The results will be presented in a sequential way through three graphs Figure 9, Figure 10 and Figure 11, each one representing the evolution of SPI(t) and SPI($) during the period of the project. The three sets of results will then be combined in a final-graph presenting their average, in order to give an overall view of the trend observed across the projects.

Figure 8: SPI comparison over time Project 1



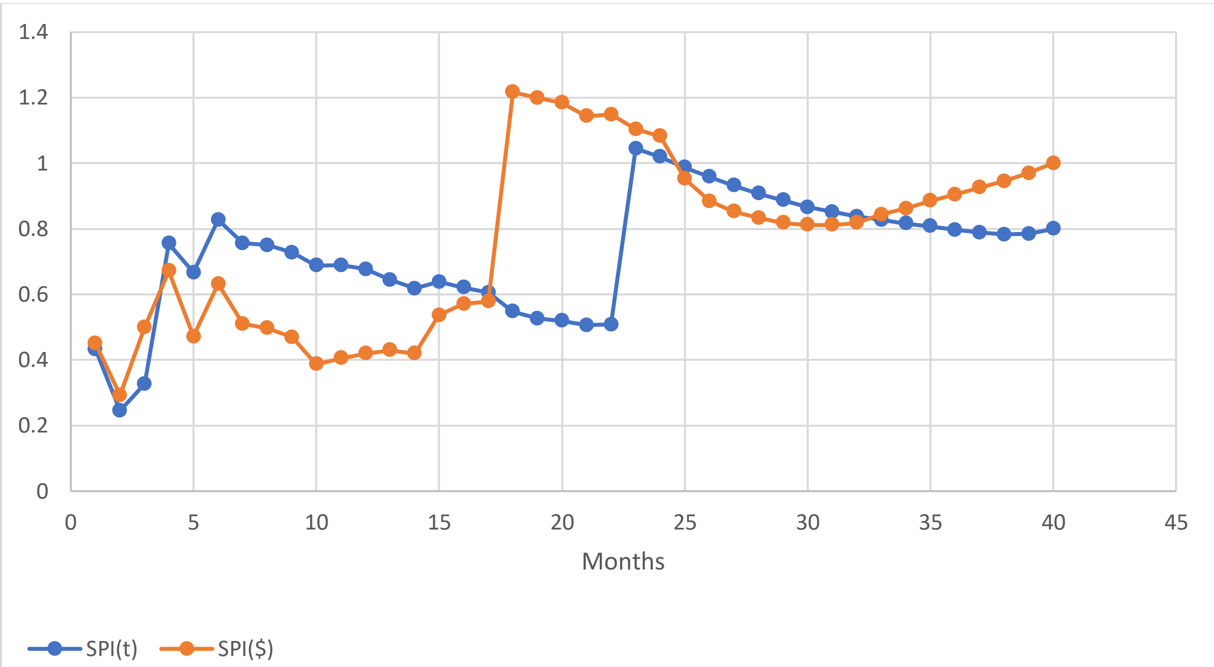
Source: Elaborated by authors

Figure 9: SPI comparison over time Project 2



Source: Elaborated by authors

Figure 10: SPI comparison over time Project 3



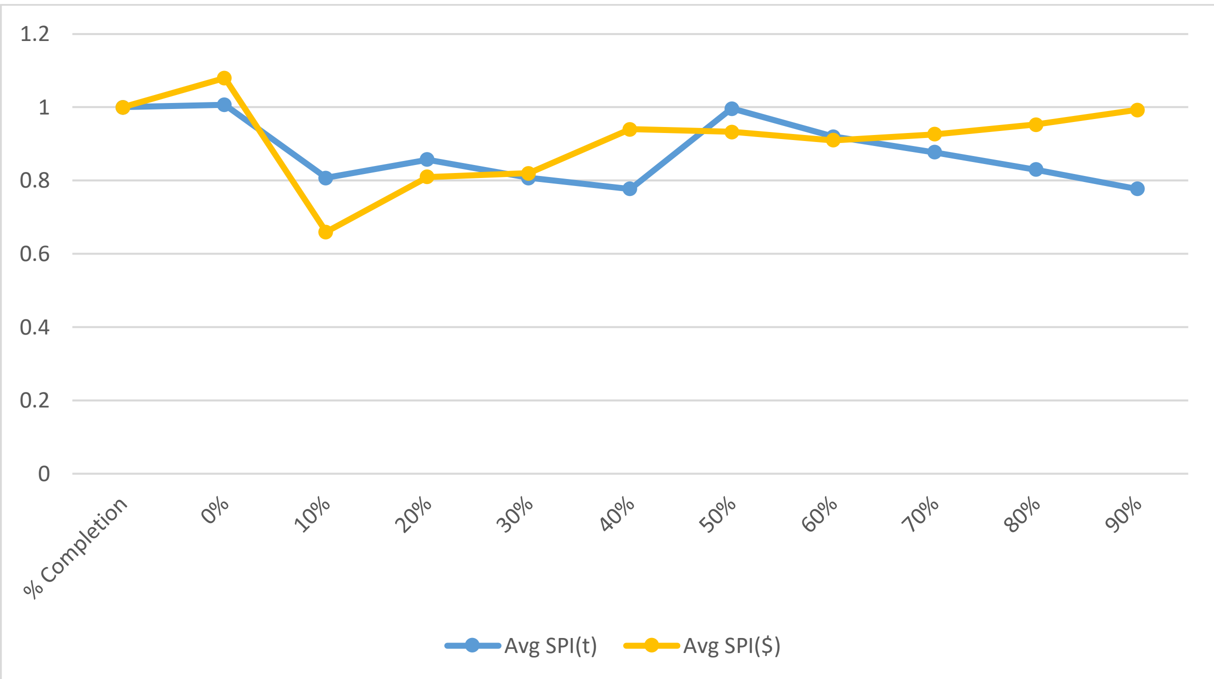
Source: Elaborated by authors

As can be seen from the SPIs depicted in Figures 8, 9, and 10, SPI(t) and SPI($) demonstrate nearly identical trends at the beginning of the analysis for all of the projects considered; however, there are discrepancies in the level of separation between the two indicators from project to project. At times the two SPIs coincide, whereas on other occasions SPI($) demonstrates more volatile behavior than SPI(t). It is also apparent from the figures provided that SPI(t) and SPI($) do not both cross the 0.90 line at the same time or spend the same amount of time below this line.

With increasing progression of the projects, a difference between the two SPIs becomes obvious from all of the above-presented figures, where SPI(t) maintains its position on lower levels or continues to fall, while SPI($) rises up to its previous level of 1.0. In such a way, the pattern is identical for the three presented charts, although there are some differences in timing between the projects analyzed. Accordingly, SPI(t) drops below 0.90 line or remains under this point of time for longer than SPI($).

An exception worth mentioning can be seen from Figure 10 as both SPI(t) and SPI($) take a steep rise between periods 17-23, reaching values higher than 1. The upward swing in both metrics is a temporary phenomenon caused by project-related changes in that stage affecting the cost-based schedule performance indicator. From period 24 onwards, both the metrics tend to behave as per the overall behavior exhibited in Figures 8 and 9; whereas SPI($) reaches 1.0 again and SPI(t) stays lower than that value. Therefore, the use of SPI(t) can be considered more sensitive in indicating the presence of any schedule problems within the projects.

Figure 11: Average SPI comparison over the projects completion %



Source: Elaborated by authors

As shown in the graph above, the average SPI for the project comparison chart presented above includes the results obtained in Figures 8, 9, and 10. The chart shows the behavior of the average SPI(t) and SPI($) in the course of implementation of the three selected EPC projects.

It can be stated that there is a constant repetition in the behavior of the average graph, which is observed within the first 20 percent of the project completion. As the figures indicate, the SPI(t) and SPI($) behave identically. Both indicators start at the same level 1.0 and drop below 0.90 between 10% and 20% completion of the project. In this case, it can be said that the average SPI(t) is equal to approximately 0.81 while SPI($) is slightly lower.

However, when the project passes the 50% mark, the graphs diverge dramatically. As a result, SPI($) gradually returns to its initial level of 1.0, crossing the 0.90 boundary point and reaching its initial value. At the same time, SPI(t) remains below the 0.90 line throughout the project duration and ends at approximately 0.78. Such an averaged value thus indicates the overall trend of SPI operation in EPC project management.

The continuous difference between these two variables in the final stages of the project, observable in their average, shows that SPI($) consistently underestimates schedule slippage after the midpoint of implementation.

1.2.2 Test 2: Evaluation of the Divergence between SV(t) and SV($)

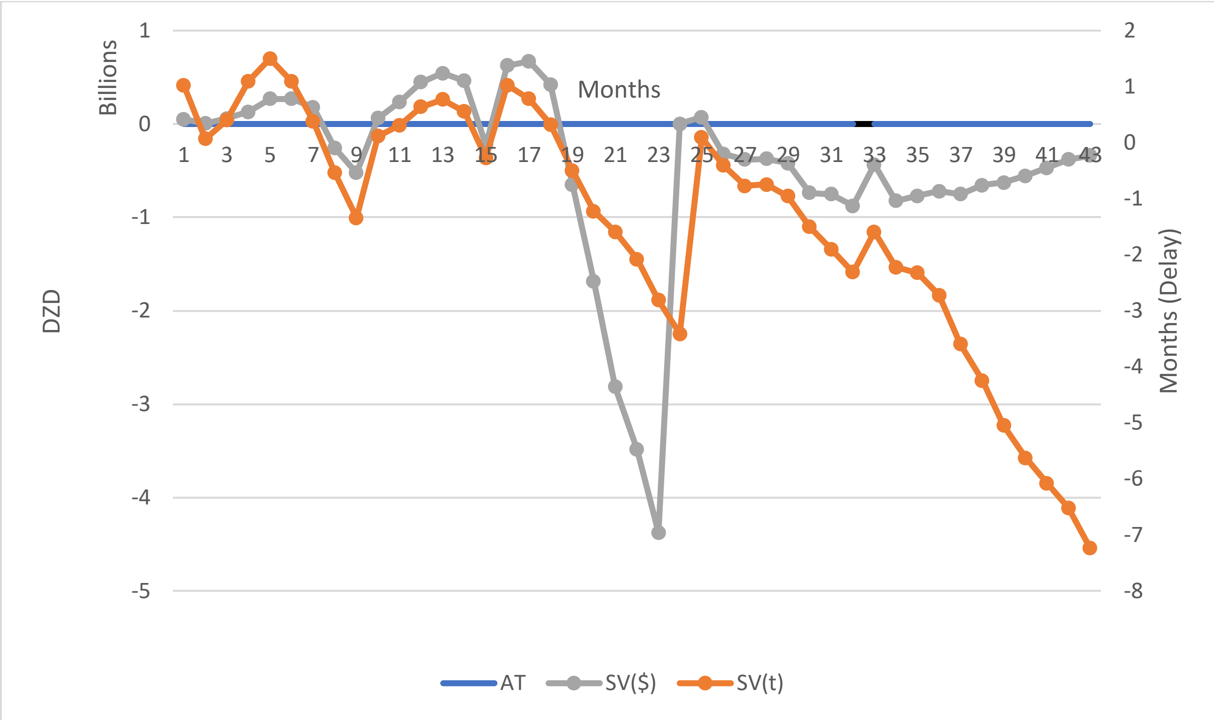
The second test centers around the analysis of the relationship between schedule variance, denoted as SV(t), and schedule variance measured in monetary units, referred to as SV($). In this case, both indicators were evaluated and represented in scatter plots for each project within the dataset. A scatter plot was created for each project using two vertical axes, where one is expressed in monetary terms representing the variance in earned value, and another one in terms of time representing the variance in earned schedule.

The aim of the current test is to determine the point in project implementation during which

SV(t) and SV($) start to diverge.

The analysis of Schedule Variance in Figures 12, 13, and 14 is indicative of the pattern of change for SV(t) and SV($) in the course of Projects P1, P2, and P3 respectively. At the initial stages of projects, the indicators have similar behavior, although the deviation between them is different for all three graphs. In all three instances, initially the SV($) has the same direction as SV(t). However, after a certain point in time it ceases having the initial trend and becomes closer to zero, which can be regarded as the point of divergence between these indicators.

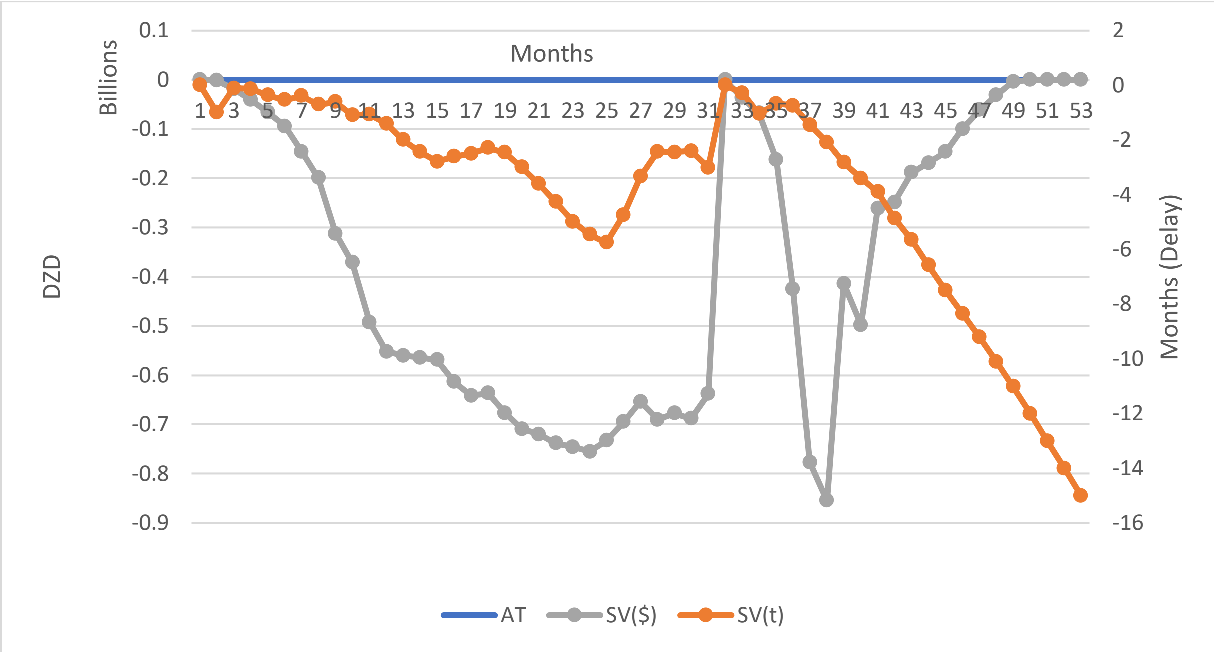
Figure 12: SV divergence point Project 1



Source: Elaborated by authors

According to Figure 12, the divergence happens when about 78% of work has been accomplished. Until that moment both indicators demonstrate worsening conditions in terms of schedules, while SV($) becomes close to zero after the divergence whereas SV(t) remains on its negative trajectory.

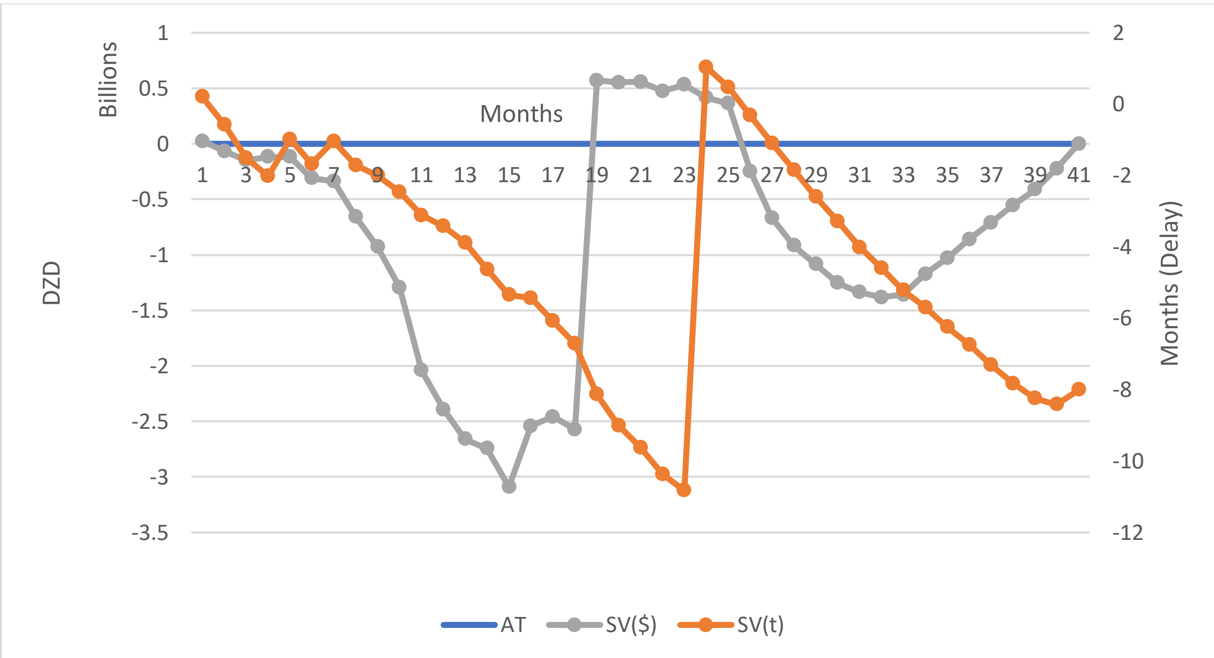
Figure 13: SV divergence point Project 2



Source: Elaborated by authors

According to Figure 13, the divergence happens a bit later namely when the accomplishment level reaches about 79%. From the point onwards, the schedule variance becomes more negative, while the SV($) goes down and converges to zero value by the period 53 when the value of SV(t) is -15 months.

Figure 14: SV divergence point Project 3

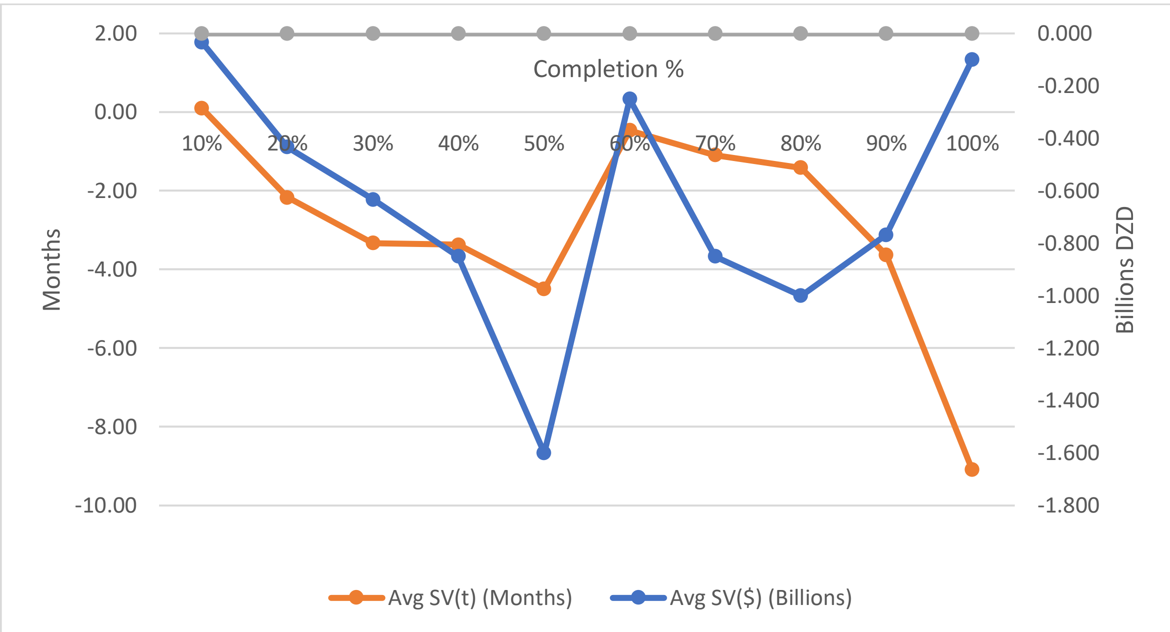


Source: Elaborated by authors.

However, one interesting thing can be seen in the graph in figure 14 from periods 17 through 23. In this case, there is a sudden spike in both SV(t) and SV($) towards the positive side, taking it almost to +500M and after that, going back to negative values. Such an anomaly does not depict any particular behavior of the indicator; instead, this was because of a project-specific change that took place during this period and caused temporary interruption to the cost-based variances. However, beyond period 25, SV($) again tends to fall back to zero, just like in Figures 12 and 13.

The point of divergence for all the three figures lies around 77% - 81% completion of the project, and after this point, the regression of SV($) towards zero and continued downward trend of SV(t) can be observed.

Figure 15: Average SV divergence point



Source: Elaborated by authors

Generally, the graphs of Schedule Variance ($), and Schedule Variance (t) provided in Figures 12, 13, and 14 can be plotted as an average Schedule Variance graph presented above.

At the initial stage of the project implementation, both indicators have similar behavior since they go down and reach the negative side. Thus, such a trend indicates that schedule management gets worse. The correlation between the indicators shows that during the project execution process, there is a direct relationship between Schedule Variance ($) and Schedule

Variance (t) because they send the same message to the project manager regarding the schedule variance.

However, the most distinctive feature that can be seen in the above-mentioned averaged graph is the point of divergence. It occurs when 80% of the project is completed. After that point, the behavior of Schedule Variance ($) and Schedule Variance (t) becomes completely opposite. While Schedule Variance ($) begins to become better and ultimately reaches zero (that is, provides an illusion of problem solution with schedule variance), Schedule Variance (t) still goes down to become the most negative (approximately -10 months on average).

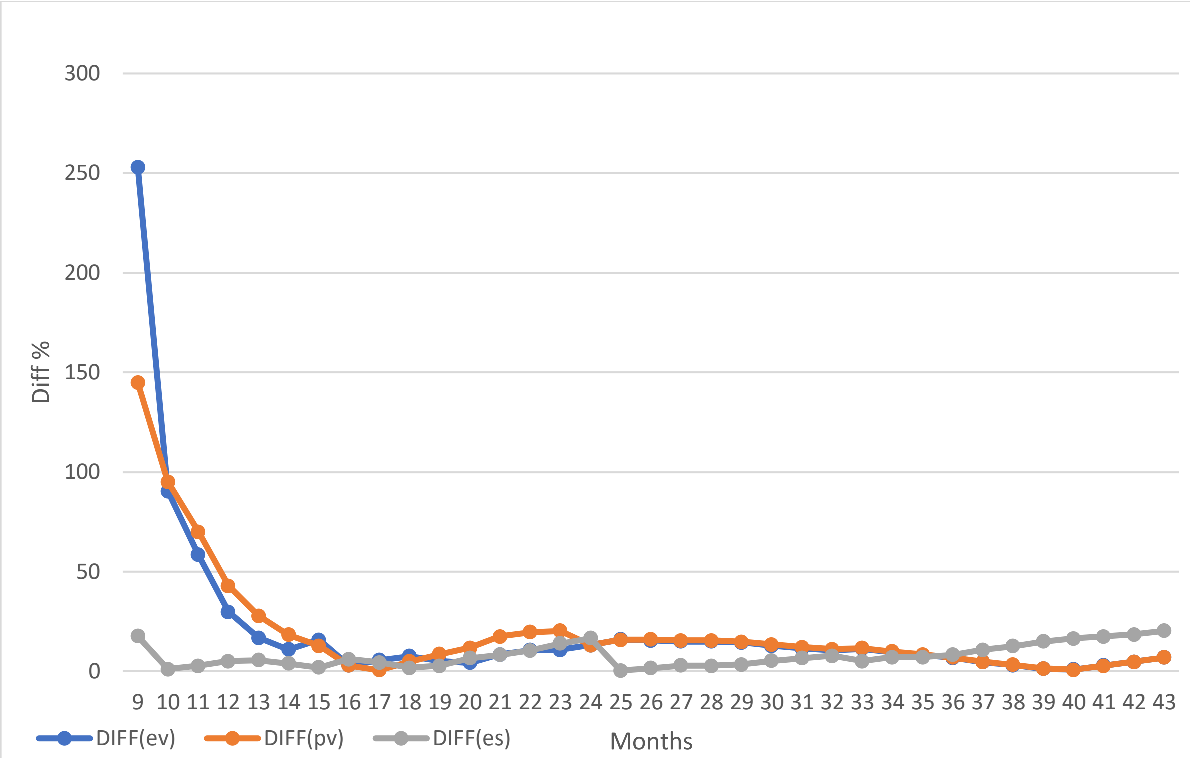
Thus, the averaged Schedule Variance graph presented above reflects the typical Schedule Variance behavior in EPC projects.

1.2.3 Test 3: Forecasting Accuracy Comparison

Test 3 will measure how accurate three methods of forecasting durations IEAC(EV), IEAC(PV) and IEAC(ES) are in forecasting the project's final duration. As it was discussed in the literature above, the IEAC(EV) and IEAC(PV) methods are based on cost performance and use PV and EV averages, respectively, while the IEAC(ES) method uses only time units by applying the formula SPI(t). In order to compare the methods' accuracy, the percent difference between the forecasted duration and the actual one was measured in all periods throughout the project duration. Three figures, Figure 17, Figure 18 and Figure 19 will be used for presentation purposes.

The objective of this test is to determine which method results in the least and most stable percent difference from the actual duration throughout the project implementation process.

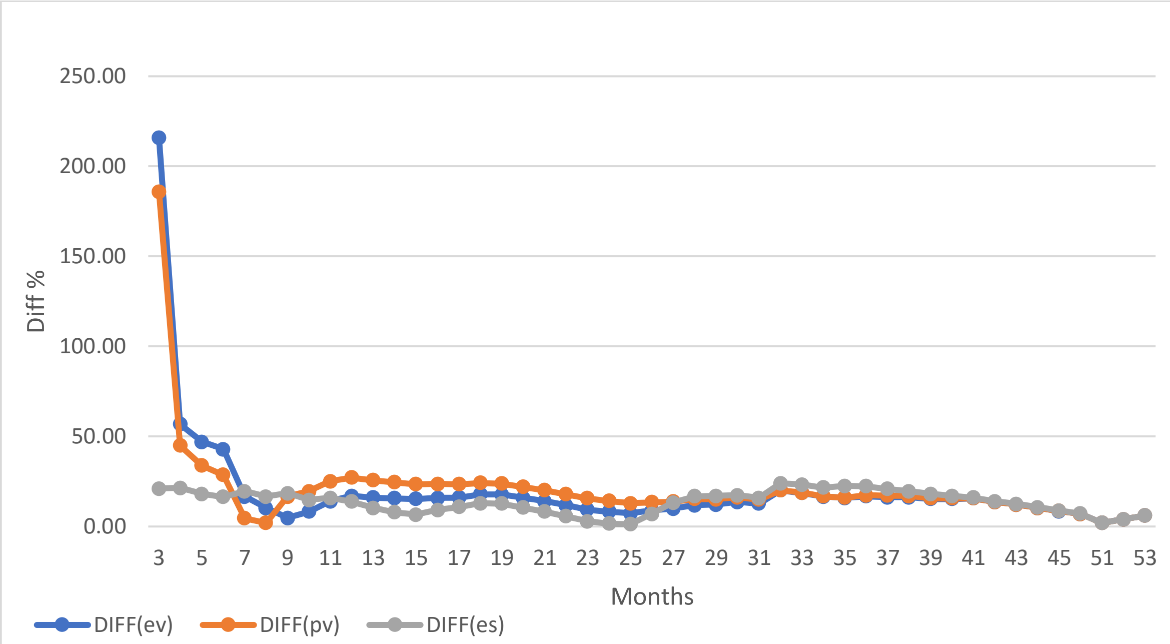
Figure 16: Percent Difference Results for Final Duration Forecast–Project 1



Source: Elaborated by authors

Based on Figure 17 above, it is noted that the DIFF IEAC(PV) and DIFF IEAC(EV) lines initially exhibit a large percentage difference of around 250% and 145% at the ninth month, respectively, until the difference quickly drops to around 10% – 20%. Both lines exhibit relatively close percentages after approximately the 17th month up to the end of the project, which means that the difference between the two will always be lower than 20%. Meanwhile, the DIFF IEAC(ES) line appears to be far lower from the other two lines, having values from approximately 0% – 20%, thereby illustrating a relatively stable and controlled percentage throughout the course of the project.

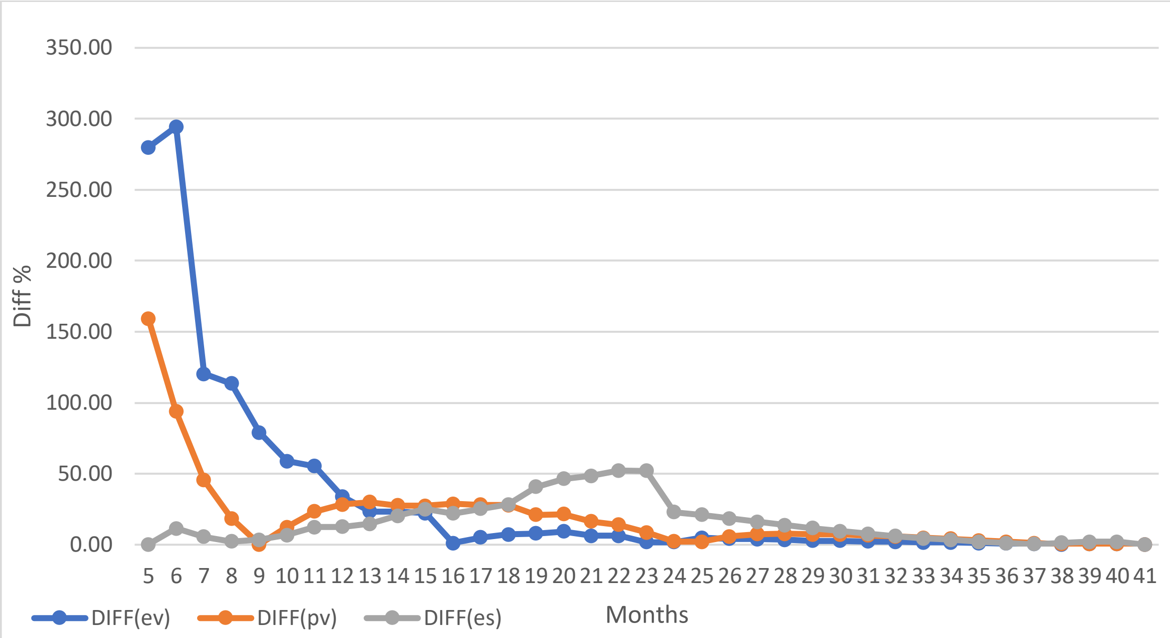
Figure 17: Percent Difference Results for Final Duration Forecast–Project 2



Source: Elaborated by authors

From Figure 18, it can be seen that the DIFF IEAC(PV) and DIFF IEAC(EV) graphs begin with a large percentage difference, reaching about 185% and 215% at month 3, respectively, after which there is a drastic decline towards stabilization. Both curves descend quite sharply and drop below 50% at month 5, further declining and stabilizing between 10-25% starting from about month 9 for the rest of the project life cycle, ending at month 53. The two curves behave similarly to each other, staying relatively close to each other during the middle and later stages of the project. On the other hand, the DIFF IEAC(ES) curve is considerably lower than both curves, staying stable within the range of approximately 0% to 25% from the very beginning of its report at month 3, reflecting a much more consistent performance than the other two forecasting methods during the whole project life cycle.

Figure 18: Percent Difference Results for Final Duration Forecast–Project 3

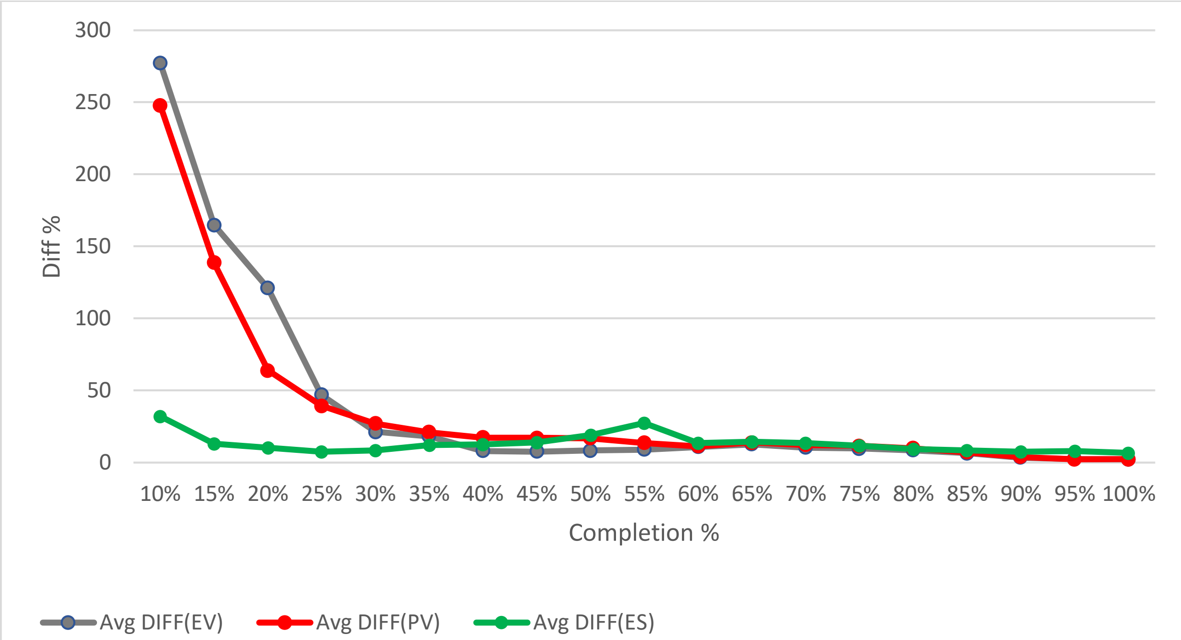


Source: Elaborated by authors

As seen in Fig. 19, DIFF IEAC(EV) and DIFF IEAC(PV) both begin with extremely high percentage differences, reaching a maximum of about 295% and 160% respectively at month 6, after which there is a dramatic drop to settle in the 10%-30% range from month 13 onward. DIFF IEAC(ES), on the other hand, remains fairly constant at extremely low levels, fluctuating within the 0%-25% range in the majority of reporting periods. There is one deviation from the trend, however, in the months 17 to 23 when DIFF IEAC(ES) spikes to roughly 55%, overtaking DIFF IEAC(EV) and DIFF IEAC(PV), due to a project adjustment in this period; then it resumes its usual low percentage difference and eventually converges towards zero at month 41.

In all three projects, a similar consistent trend appears: whereas DIFF IEAC(EV) and DIFF IEAC(PV) both exhibit highly unreliable initial forecasts and only become reliable in later periods, DIFF IEAC(ES) continues to be more accurate from the beginning, indicating that IEAC(ES) achieves forecasting accuracy much earlier than the others.

Figure 19: Average Percent Difference Results for Final Duration Forecast



Source: Elaborated by authors

The aggregated graph shows that the forecasting characteristics of all three EPCs follow the same pattern as those analyzed separately. The starting points of both AVG DIFF(EV) and AVG DIFF(PV) have high forecasting errors, about 275% and 250% respectively at 10% project completion, while decreasing rapidly and trending towards zero as project completion nears. This demonstrates that cost-based forecasting methodology is highly unreliable in the initial stages of project execution. In the case of AVG DIFF(ES), forecasting is highly stable and reliable throughout the whole project life cycle, from 8% up to about 35%, and even reaches an additional small peak at 55% completion point, after which it continues trending down steadily. This proves that the schedule-based forecast methodology allows forecasting reliability to be achieved far sooner than cost-based methodologies, specifically in the most crucial stages of project control decision-making.

2 Discussion

In this section, an interpretation of the results obtained through the qualitative interviews and the quantitative analysis of the case study is presented, exploring its implications in relation to the research problem. The analysis of the results takes place in two parallel dimensions: the real organizational world of EVM in SARPI and the performance of the ES indicators against the traditional ones.

2.1 Synthesis and Interpretation of Interview Findings

The results that can be derived from the analysis of four semi-structured interviews, carried out at SARPI, lead to the formation of a coherent and analytical description of the current project performance management methods within this company. EVM emerges as a fully institutionalized method, which is used on a continuous basis throughout all stages of EPC projects, and utilized at several organizational levels starting from the actual tracking of project costs and schedules and finishing with the reporting and decision-making of the directorate level. All indicators, including PV, EV, AC, CPI, SPI, and SV, are calculated in practice and incorporated into the controlling process. Nevertheless, in spite of the advanced stage of EVM implementation, there appears one problem that becomes evident as a result of the analysis of the interviews: the classic indicators of schedule SPI($) and SV($) become meaningless for the assessment of schedule management as the project nears its completion. These factors, together with the intrinsic complexity of analyzing cost-oriented variables in temporal terms, make these measures inadequate as independent means for forecasting time reliably at any point during the entire project life cycle. Most importantly, none of the interviewees, regardless of their organizational position, knew about the concept of Earned Schedule as a potential solution to this problem, thus indicating the existence of a clear mismatch between organizational requirements and existing methodologies. However, all four interviewees showed openness to implementing more reliable time forecasting procedures, but only if proven effective using real-world data, which is exactly the goal that the empirical part of this dissertation aims to achieve.

2.2 Synthesis and Interpretation of Case Study Results

2.2.1 Test 1: Study of SPI(t) and SPI($) Below 0.90 Through Time

The results of Test 1 confirm, on real EPC project data, the known theoretical limitation of the cost-based schedule performance index. As demonstrated by Lipke and corroborated by subsequent studies, SPI($) is mathematically constrained to converge toward 1.0 as earned value approaches the total budget at completion, regardless of whether the project finishes on time or behind schedule. This convergence renders SPI($) progressively less informative in the final stages of a project, precisely when reliable schedule information is most critical for management decision-making.

SPI(t), by contrast, does not share this mathematical constraint. Because it is referenced to time rather than cost, it retains sensitivity to schedule conditions throughout the full project duration and continues to reflect the actual state of schedule performance even in the closing phases of execution. The averaged results shown in Figure 12 make this distinction particularly clear: at 90% completion, SPI(t) stands at approximately 0.78 remaining below the 0.90 threshold and accurately signaling that all three projects finished behind schedule while SPI($) has effectively returned to 1.0, offering no useful diagnostic information at that stage.

These findings carry a direct implication for project control practice in EPC environments. An organization relying solely on SPI($) for schedule monitoring risks receiving a falsely reassuring signal in the second half of project execution, underestimating the extent of delay and potentially deferring necessary corrective action. The consistent behavior of SPI(t) across the three projects studied suggests that its integration into the project monitoring framework would provide a more reliable and actionable basis for schedule management throughout the full project lifecycle. It is evident that the findings in question are entirely consistent with the theories and findings by (Lipke, 2012). Both scholars have demonstrated that SPI($) lacks diagnosticity when approaching the end of project execution whereas SPI(t) remains sensitive to schedule dynamics. This consistency further strengthens the relevance of the behavior observed in the current study to other settings.

2.2.2 Test 2: Evaluation of the Divergence between SV(t) and SV($)

The results of Test 2 provide strong evidence that SV($) and SV(t) do not carry equivalent informational value throughout the full project lifecycle. In the early and middle phases of execution, the two indicators move in the same direction and communicate the same schedule management signal, making either one a viable basis for decision-making during that period. However, once a project passes approximately the 80% completion mark, this equivalence breaks down.

The recovery of SV($) toward zero in the final stages of a project is not a reflection of genuine schedule improvement. It is a mathematical consequence of the EVM framework: as earned value approaches the budget at completion, the difference between EV and PV necessarily diminishes, driving SV($) toward zero regardless of the actual time overrun being accumulated. The project manager who relies solely on SV($) at this stage is therefore exposed to a structurally misleading signal one that suggests schedule conditions are normalizing when, in reality, the project is continuing to fall further behind schedule.

SV(t), by contrast, is not subject to this mathematical convergence. Because it measures the gap between earned schedule and actual time, it remains sensitive to schedule conditions throughout the entire project duration and does not artificially recover as the project nears completion. The averaged value of approximately 10 months recorded at project completion accurately reflects the delays experienced across the three EPC projects studied, whereas the corresponding averaged SV($) has effectively converged to zero.

These findings carry a direct practical implication for EPC project management. The systematic use of SV(t) alongside or in place of SV($) for schedule monitoring in the second half of project execution would provide project managers with a more accurate and actionable reading of schedule variance, enabling earlier identification of unresolved delays and more timely corrective intervention before project completion. These results are perfectly consistent with the findings of (Vandevoorde & Vanhoucke, 2006) who found out that SV($) gives inconsistent outputs at the final stage of the project, and (Lipke, 2012) who proved through theoretical calculations that SV($) must converge irrespective of its schedule performance.

2.2.3 Test 3: Forecasting Accuracy Comparison

The findings from Test 3 provide solid evidence of a significant and consistent difference in terms of accuracy of forecast in comparison between the Earned Schedule approach and the two cost-based EVM forecasting approaches used on the three different EPC projects analyzed.

Both the Diff IEAC(EV) and Diff IEAC(PV) forecasting techniques have one major flaw that they both share the dependency on the cumulative average work rate based on either the earned value (EV) or planned value (PV), making both of them highly sensitive to past performance. According to individual charts for each project and aggregated data, both of them start off with extremely high forecast errors in early stages, reaching 275% and 250%, respectively, in the 10% completion period, and then finally converging towards actual duration near the end of the project at the stage when forecast information becomes less meaningful for making adjustments to project performance.

The Diff IEAC(ES), on the other hand, is based entirely on SPI(t). The SPI(t), being a time-based index, is less likely to suffer from the problems caused by the early cost variance, and it converges relatively quickly through the course of the project life cycle. It can be seen from all three graphs and further evidenced by the average graph that the Diff IEAC(ES) value is always maintained between 8% to 35%, throughout the entire project life cycle. This allows the project manager to derive an estimate of the total project duration, while there is enough time left for remedial action.

However, the temporary deviation in Diff IEAC(ES) seen in Figure 19 of Project 3, when it briefly increases up to around 55% between months 17 and 23 and temporarily exceeds the values of Diff IEAC(EV) and Diff IEAC(PV), cannot be used to negate this general observation. According to Tests 1 and 2, this was caused by an incident within the project that caused a temporary increase in SPI(t). However, the forecasting accuracy of Diff IEAC(ES) returns to normal as soon as this incident is factored out, and the value of Diff IEAC(ES) starts to decrease gradually until it reaches zero at project completion.

In summary, the findings of Test 3 provide empirical evidence that the estimation of remaining duration using IEAC(ES) is a practically superior option compared to the conventional cost-based forecasts used in EVM, especially when it comes to forecasting the duration of EPC projects involving lengthy and complicated construction processes. The fact that IEAC(ES) is capable of providing earlier and smoother convergence to the actual duration, as well as being less prone to inflation errors than IEAC(EV) and IEAC(PV), makes it the preferred choice for forecasting duration throughout the whole project cycle. This research is consistent with the findings by (Bruchey, 2012a) and (Lipke, 2009), which show that for any set of projects considered, the IEAC(ES) method invariably proves to be superior to the use of costs as forecasting parameters throughout all phases of the projects' life cycle. This study extends such findings to an EPC industry setting.

Chapter's conclusion:

In this regard, the results and discussion described in this chapter represent a comprehensive and mutually reinforcing set of empirical data to respond to the research question. First of all, the findings from the interviews' thematic analysis have confirmed that although EVM is officially and actively utilized by SARPI in the context of its activities at both operational and strategic levels, the traditional schedule indicators used in the process of EPC projects' evaluation are not considered reliable enough especially in the late stages of the projects when their convergence effect distorts actual measurements. Second, the results of the analysis performed within the case study framework and based on the quantitative analysis of empirical data have provided the evidence that Earned Schedule can be a more reliable tool for measuring schedule performance. Such findings are quite similar to those found in the reviewed literature, in particular those discussed by (Lipke, 2009, 2012), (Vandevoorde & Vanhoucke, 2006), and (Bruchey, 2012). Specifically, they all managed to prove theoretically and practically that there were structural constraints in terms of schedule indicators under EVM and that Earned Schedule was more reliable throughout the entire project life cycle. The current research complements and confirms such results by proving for the first time empirically that such an approach is valid within the real-life EPC industry.

CONCLUSION

Synthesis and Overview

This dissertation was designed to tackle an important challenge in the realm of project performance measurement, which is to determine how effective the application of ES is as a basis for schedule performance evaluation and duration prediction as compared with the use of EVM in EPC project management practices at SARPI. In order to answer this question, the study relied on two distinct approaches, namely a qualitative approach that involved the conduct of four semi-structured interviews with project control specialists and a quantitative approach that entailed the application of EVM and ES metrics to three EPC projects. The two approaches were able to yield an integrated set of findings that addressed the various secondary research questions posed in the study. The interviewees confirmed that the organization officially and unequivocally embraces the EVM approach, employing it consistently throughout the entire lifecycle of each project, from the beginning until its completion, and deploying it not only operationally but also strategically for decision-making purposes. All key metrics, such as planned value, earned value, actual cost, cost performance index, schedule performance index, and schedule variance, are regularly computed and incorporated into performance monitoring. Yet, despite this advanced stage of EVM implementation, all interviewees from different hierarchical positions spontaneously and autonomously pointed out one common flaw within the framework the similarity of schedule indicators to neutral figures during the last stages of implementation, making them deceptive at the most important time in project management. Notably, none of the four interviewees from engineer to director previously knew about the Earned Schedule concept.

Main Findings

The findings from Test 1 have been successful in showing, using actual EPC project data, that the two performance indicators react similarly during the early stages of execution. However, once past the 50% milestone, there is a clear deviation; SPI($) steadily returns towards 1.0, thus disguising the accumulated slippage, whereas SPI(t) continues to fall well below the critical 0.90 value and ends up averaging out at about 0.78 for all three projects. Therefore, it can be concluded that SPI(t) is clearly a better measure of schedule slippage during the later stages of execution than SPI($).

Test 2 pinpointed the point of departure for the two metrics in approximately 80% of the project's progress in all three projects. At this point, the two metrics send out identical signals regarding the schedule, making either one equally applicable. Post this mark, SV($) creates a fake impression of schedule recovery as it artificially approaches zero, whereas SV(t) takes a further decline, culminating in an average of −10 months at the end of each of the projects. This indicates that the sole reliance on SV($) in the final fifth of the project can lead to a deceptive signal, hindering the ability to detect any delays.

In Test 3, it has been consistently established for all three project scenarios that IEAC(ES) provides smaller percent differences in comparison to the true value of the final project duration at any stage of the project life cycle. Whereas IEAC(EV) and IEAC(PV) start off with forecasting errors between 50% and 75%, respectively, and become accurate only in the last 10-20% of project execution, IEAC(ES) comes within a narrow range of forecasting errors between 8% and 25%. The significance of such superior performance lies in its application right from the start of the project execution process when there is still enough time for corrective measures.

All taken into account, the results of this study show that the Earned Schedule approach is proven to be statistically and reliably superior to the classic EVM measures for the purposes of schedule management and duration forecast in terms of the entire life cycle of the EPC project – which is objectively proven already at its early stages.

Limitations and Future Perspectives:

The first limitation of this study relates to the relatively small sample size used. While the three projects examined yielded consistent results and complete lifecycle data, these findings are best taken as empirical indications rather than statistically validated outcomes. The future research is thus recommended to: Repeat the same three analytical tests using a larger sample size of fully implemented EPC projects in order to statistically validate the discovered behavior patterns and generalize the findings. Apply the analysis to other Algerian industry companies, whether public or privately owned, to evaluate if the same limitations inherent to classical EVM schedule measurements, as well as their inferiority compared to ES measures, can also be generalized to other organizational types and business environments. Test the feasibility of using other performance management techniques in the Algerian EPC setting, such as CCPM, Agile Earned Value approaches, or hybrid models combining EVM with probabilistic schedule evaluation.

BIBLIOGRAPHY

A guide to the project management body of knowledge (PMBOK® Guide) (7th ed.). (2021). Project Management Institute.

Agumalu, S. A. (2022). A Predictive Cost-Management and Benefits Realization Model for International Projects Using Earned Value Management (EVM) to Reduce Cost Overruns and Improve Project Outcomes. *International Journal of Research Publications in Engineering, Technology and Management*. https://doi.org/10.15662/IJRPETM.2022.0502005

Akhtar, M. (2020). Dealing with EPC Project Management Problems and Challenges A Case Study on Petrochemical, Oil and Gas EPC Projects in Middle-East. *Abu Dhabi International Petroleum Exhibition & Conference*, D031S084R001. https://doi.org/10.2118/203431-MS

Ballesteros-Pérez, P., & Elamrousy, K. M. (2018). ON THE LIMITATIONS OF THE EARNED VALUE MANAGEMENT TECHNIQUE TO ANTICIPATE PROJECT DELAYS. *Proceedings of International Structural Engineering and Construction*, *5*(1). https://doi.org/10.14455/ISEC.res.2018.43

Bruchey, W. J. (2012). *A Comparison of Earned Value and Earned Schedule Duration Forecast Methods on Department of Defense Major Defense Acquisition Programs*.

Cantarelli, C. C., Flyvbjerg, B., Molin, E. J. E., & Wee, B. V. (2010). Cost Overruns in Large-scale Transportation Infrastructure Projects: Explanations and Their Theoretical Embeddedness. *European Journal of Transport and Infrastructure Research*. https://doi.org/10.18757/EJTIR.2010.10.1.2864

Cioffi, D. F. (2006). Designing project management: A scientific notation and an improved formalism for earned value calculations. *International Journal of Project Management*, *24*(2), 136–144. https://doi.org/10.1016/j.ijproman.2005.07.003

Corovic, R. (2006). *Why EVM Is Not Good for Schedule Performance Analyses (and how it could be…)*.

Eirgash, M. A. (2021). Project Monitoring and Early Warning of Time-Cost Overruns in Earned Value Management. *Current Trends in Civil & Structural Engineering*, *7*(5). https://doi.org/10.33552/CTCSE.2021.07.000673

Fleming, Q. W., & Koppelman, J. M. (2010). *Earned value project management* (4th ed). Project Management Institute.

Garel, G. (2013). A history of project management models: From pre-models to the standard models. *International Journal of Project Management*, *31*(5), 663–669. https://doi.org/10.1016/j.ijproman.2012.12.011

Gibson, G. E., Wang, Y.-R., Cho, C.-S., & Pappas, M. P. (2006). What Is Preproject Planning, Anyway? *Journal of Management in Engineering*, *22*(1), 35–42. https://doi.org/10.1061/(ASCE)0742-597X(2006)22:1(35)

Hansen, S. (2015). *STUDY ON THE MANAGEMENT OF EPC PROJECTS*.

Henderson, K. (2003). *Earned Schedule: A Breakthrough Extension to Earned Value Theory?, A Retrospective Analysis of Real Project Data*.

Kelly, J., Male, S., & Graham, D. (2015). *Value management of construction projects* (2nd edition). John Wiley & Sons Inc.

Kim, E., Wells, W. G., & Duffey, M. R. (2003). A model for effective implementation of Earned Value Management methodology. *International Journal of Project Management*, *21*(5), 375–382. https://doi.org/10.1016/S0263-7863(02)00049-2

Lipke, W. (2009). *Project Duration Forecasting … A Comparison of Earned Value Management Methods to Earned Schedule*. (2).

Lipke, W. (2012). *Earned Schedule Contribution to Project Management*.

Lipke, W. (2015). *Testing Earned Schedule Forecasting Reliability*.

Lipke, W. (2017). *Assessing Earned Value Management and Earned Schedule Forecasting*.

Loots, P., & Henchie, N. (2007). *Worlds Apart: EPC and EPCM Contracts: Risk issues and allocation*.

Love, P. E. D., Sing, C.-P., Carey, B., & Kim, J. T. (2015). Estimating Construction Contingency: Accommodating the Potential for Cost Overruns in Road Construction Projects. *Journal of Infrastructure Systems*, *21*(2), 04014035. https://doi.org/10.1061/(ASCE)IS.1943-555X.0000221

Phillips, C. R., Moder, J. J., Davis, E. W., Moder, J. J., & Davis, E. W. (1983). *Project management with CPM, PERT and precedence diagramming* (3. ed). Van Nostrand Reinhold.

Proaño-Narváez, M., Flores-Vázquez, C., Vásquez Quiroz, P., & Avila-Calle, M. (2022). Earned Value Method (EVM) for Construction Projects: Current Application and Future Projections. *Buildings*, *12*(3), 301. https://doi.org/10.3390/buildings12030301

Rachid, Z., Toufik, B., & Mohammed, B. (2019). Causes of schedule delays in construction projects in Algeria. *International Journal of Construction Management*, *19*(5), 371–381. https://doi.org/10.1080/15623599.2018.1435234

Rui, Z., Peng, F., Ling, K., Chang, H., Chen, G., & Zhou, X. (2017). Investigation into the performance of oil and gas projects. *Journal of Natural Gas Science and Engineering*, *38*, 12–20. https://doi.org/10.1016/j.jngse.2016.11.049

Turner, J. R., Grude, K. V., & Thurloway, L. (2009). *The project manager as change agent: Leadership, influence and negotiation*. McGraw-Hill.

Vandevoorde, S., & Vanhoucke, M. (2006). A comparison of different project duration forecasting methods using earned value metrics. *International Journal of Project Management*, *24*(4), 289–302. https://doi.org/10.1016/j.ijproman.2005.10.004

APPENDICES

APPENDIX A - INTERVIEW GUIDE & TRANSCRIPT

Axis	Question	Answers
Axis 1: Current Project Control & Forecasting Practices	Q1. Which techniques does the company employ for predicting the total cost and duration of its ongoing EPC projects?	R1: Provided no direct answer but referred the question to the Planning Manager who was considered the most suitable profile to answer the question. R2: Past experience from previous projects is regarded as the main basis for calculating costs, especially in projects where there isn't much difference between each project in terms of scale or kind. R3: The organization utilizes different methods when it comes to estimating costs and time periods of a project: analogous estimating, taking into account previous projects; parametric estimating with technical ratios; detailed bottom-up estimating according to the WBS structure; evaluating quotes from suppliers and subcontractors; scheduling with Primavera and SAP PS. R4: The process starts with making a commercial cost outline, thereby gaining cost orientation. Managers make allocations of resources for budget line items; thus, at this stage costs become clear thanks to the baseline created commercially.

Axis	Question	Answers
		Resource allocation takes place with the help of supervisors acting as advisers. However, even though there is no cost referential currently used by the organization, it was recognized that such cost referential must be created.
	Q2. Is there any consistency in the usage of these techniques among all EPC projects, or do they vary according to the size or type of the project?	R1: Has not answered directly to the raised question and recommended that Planning Manager should be the most appropriate respondent. R2: In its operations, the company utilizes a set standard methodology, but adjusts it to the specific situation of each particular project taking into account various aspects, including the geographical location, nature, and scope of work. R3: As a rule, the company works under the standard methodology – that includes a standard WBS, procedure, and template use; however, at the same time the methodology is adjusted systematically according to the nature of each particular project. This may be considered the manifestation of the philosophy "standard tools and adapting parameters." R4: Is fully agreed with R3's opinion and confirms it, adding that in the final

Axis	Question	Answers
		analysis, everything depends upon the experience of the Project Manager.
Axis 2: Application & Limitations of EVM in EPC Projects	Q3. Has the concept of Earned Value Management (EVM) been adopted as a project management technique in your organization?	**R1,R2,R3,R4**: Yes, the EVM model is definitely applied to our project officially, and we use it in all stages of the project from the beginning until project completion.
	Q4. If yes, which EVM metrics are used in practice, such as PV, EV, AC, CPI, SPI ($), and SV ($)?	**R1: R2: R3: R4:** The organization uses all the EVM metrics, including PV, EV, AC, CPI, and SPI, as part of its performance measurement process. The data from these metrics is used for strategic reporting purposes at the directorate level.
	Q5. Can the EVM schedule metrics (especially SPI ($) and SV ($)) be trusted during the entire project lifecycle?	R1: The indicators for EVM schedule are generally reliable overall. Nevertheless, the only problem with their usage concerns interpretability since the indicators are stated in terms of monetary value instead of time. Therefore, it is more advisable to use supplementary indicators stated in terms of time to get a better understanding of the indicators' implications for the project schedule. R2, R4: Did not give a direct answer and suggested that the Planning

Axis	Question	Answers
		Manager was a more suitable person to answer the question. R3: The indicators for SPI and SV are reliable at the middle stages of the project execution. Nevertheless, when approaching the end of the project, the indicators become irrelevant due to mechanical convergence of deviations to zero.
	Q6. Have you faced any issues while employing or understanding the EVM metrics in the context of EPC projects?	**R1, R3, R4**: The major limitation observed is that the sensitivity of classic EVM metrics becomes insensitive near the project end: SPI tends to approach 1 and SV approaches 0 at the project end even if there have been significant delays throughout the project. **R2**: Could not give a definitive response and referred the question to the Planning Manager who was more technically equipped to answer it.
Axis 3: Awareness & Adoption Potential of Earned Schedule (ES)	Q7. Do you have knowledge about Earned Schedule (ES), an enhanced version of EVM proposed by Walter Lipke, which calculates schedule performance based on time units instead of cost units?	**R1: R2: R3: R4:** No, Earned Schedule is not an approach which has ever been used or even mentioned during the process of planning and project control in SARPI

Axis	Question	Answers
	Q8. In case the new ES metric is validated for its effectiveness on real EPC project data, will you integrate it with your current project management system?	**R1: R2: R3: R4:** They suggested that the company would appreciate the utilization of more accurate and efficient instruments, especially those that are able to make more accurate scheduling predictions during the entire life cycle of EPC projects.

APPENDIX B – SARPI’S ORGANIZATIONAL CHART

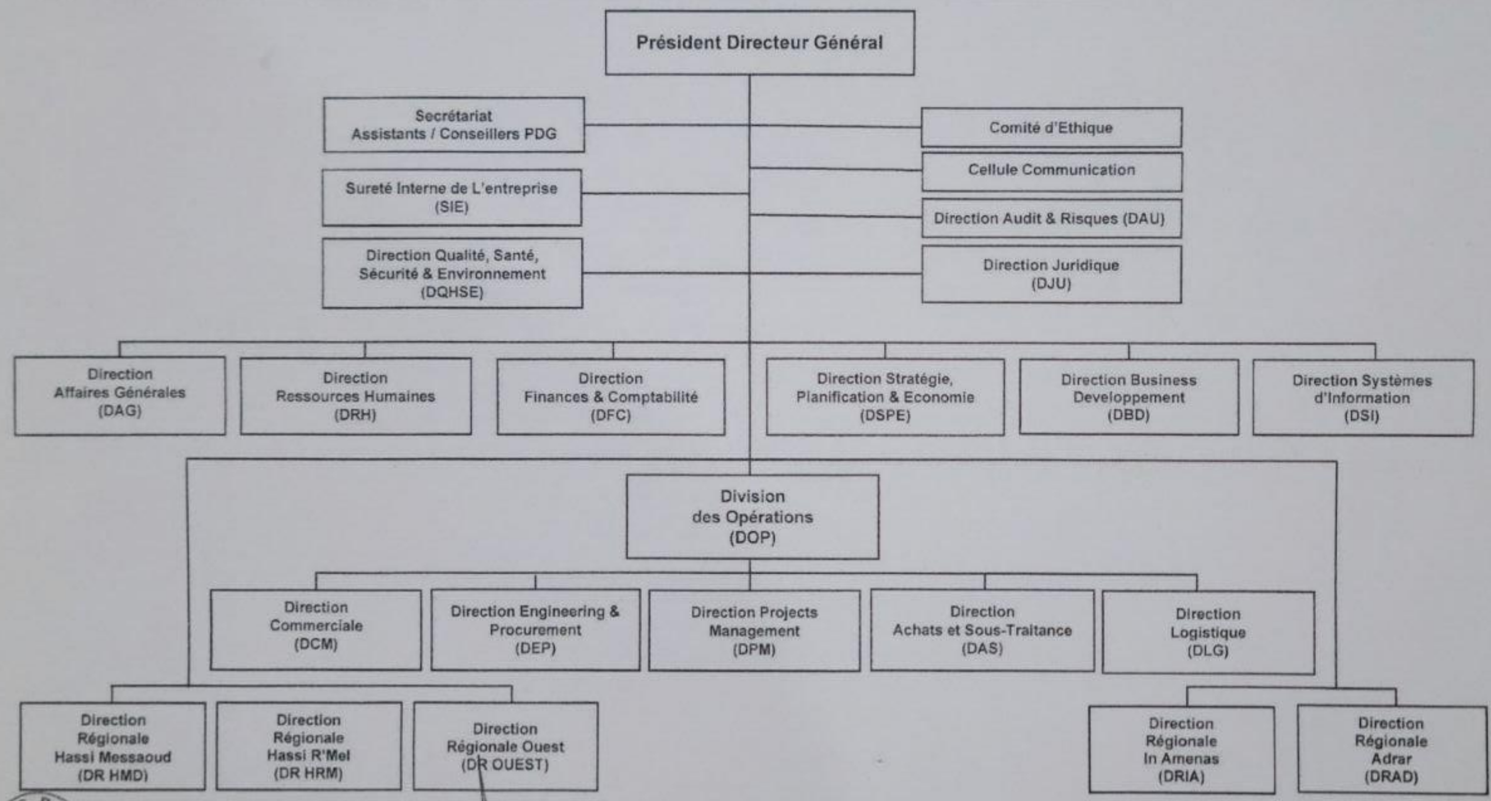
Annexe à la décision n° 038 /PDG/2025

MACRO-ORGANISATION DE SARPI SPA

Validée par le Conseil d'Administration n°04/2025 du 27/07/2025

Date : 29/07/2025

Page 1 sur 1



Le Président Directeur Général

SARPI SPA

Président Directeur Général

Annexe décision portant révision de la Macro-organisation de SARPI Spa

APPENDIX C – PROJECTS

	Name of project	Project duration	Marge (%)
PROJECT 1	Réalisation en EPC d'une station de pompes multiphasiques à RHOURDE CHEGGA (RDC) HASSI MESSAOUD	40 mois	8%
PROJECT 2	RNS - Raccordement en EPC de quatorze(14) Puits cambro-ordoviciens de hamra vers les installations existantes de Hamra	32 mois	9%
PROJECT 3	Projet de développement des champs gaziers de Tinrhert vers Alrar « Full développement »	38 mois	11%

APPENDIX D – PROJECT 1 DATA

Date	Etat_Avancement_Physique_Prevu	Etat_Avancement_Physique_Reel	AC	BAC
Sep-22	0.00%	0.30%	41,472,000.00	17,280,000,000.00
Oct-22	0.29%	0.32%	44,236,800.00	17,280,000,000.00
Nov-22	0.72%	1.05%	145,152,000.00	17,280,000,000.00
Dec-22	1.54%	2.30%	317,952,000.00	17,280,000,000.00
Jan-23	2.21%	3.77%	521,164,800.00	17,280,000,000.00
Feb-23	3.12%	4.67%	645,580,800.00	17,280,000,000.00
Mar-23	4.42%	5.47%	756,172,800.00	17,280,000,000.00
Apr-23	7.17%	5.70%	787,968,000.00	17,280,000,000.00
May-23	9.24%	6.22%	859,852,800.00	17,280,000,000.00
Jun-23	12.46%	12.81%	1,770,854,400.00	17,280,000,000.00
Jul-23	15.57%	16.94%	2,341,785,600.00	17,280,000,000.00
Aug-23	19.95%	22.54%	3,115,929,600.00	17,280,000,000.00
Sep-23	24.02%	27.17%	3,755,980,800.00	17,280,000,000.00
Oct-23	28.11%	30.78%	4,255,027,200.00	17,280,000,000.00
Nov-23	32.89%	31.60%	4,368,384,000.00	17,280,000,000.00
Dec-23	36.55%	40.18%	5,554,483,200.00	17,280,000,000.00
Jan-24	40.05%	43.93%	6,072,883,200.00	17,280,000,000.00
Feb-24	45.03%	47.47%	6,562,252,800.00	17,280,000,000.00
Mar-24	52.62%	48.86%	6,754,406,400.00	17,280,000,000.00
Apr-24	60.67%	50.92%	7,039,180,800.00	17,280,000,000.00
May-24	72.19%	55.89%	7,726,233,600.00	17,280,000,000.00
Jun-24	80.20%	60.03%	8,298,547,200.00	17,280,000,000.00
Jul-24	88.15%	62.83%	8,685,619,200.00	17,280,000,000.00
Aug-24	67.40%	67.40%	9,317,376,000.00	17,280,000,000.00
Sep-24	72.13%	72.56%	10,030,694,400.00	17,280,000,000.00
Oct-24	76.76%	74.91%	10,355,558,400.00	17,280,000,000.00
Nov-24	79.61%	77.41%	10,701,158,400.00	17,280,000,000.00
Dec-24	82.52%	80.35%	11,107,584,000.00	17,280,000,000.00
Jan-25	85.07%	82.63%	11,422,771,200.00	17,280,000,000.00
Feb-25	88.06%	83.79%	11,583,129,600.00	17,280,000,000.00
Mar-25	89.71%	85.36%	11,800,166,400.00	17,280,000,000.00
Apr-25	92.20%	87.13%	15,357,185,280.00	17,280,000,000.00
May-25	93.24%	90.73%	15,991,706,880.00	17,280,000,000.00
Jun-25	96.41%	91.64%	16,152,099,840.00	17,280,000,000.00
Jul-25	97.35%	92.90%	15,892,648,513.48	17,280,000,000.00
Aug-25	98.27%	94.11%	16,099,342,484.54	17,280,000,000.00
Sep-25	98.87%	94.51%	16,168,014,720.00	17,280,000,000.00
Oct-25	99.43%	95.63%	16,359,118,907.33	17,280,000,000.00
Nov-25	99.89%	96.26%	16,467,134,470.26	17,280,000,000.00
Dec-25	99.97%	96.76%	16,552,926,720.00	17,280,000,000.00
Jan-26	100.00%	97.28%	16,751,380,718.50	17,280,000,000.00
Feb-26	100.00%	97.79%	16,839,254,694.06	17,280,000,000.00
Mar-26	100.00%	98.05%	16,883,985,254.40	17,280,000,000.00

APPENDIX E – PROJECT 2 DATA

Projet de développ	Etat_Avancement_Physique_Prevu	Etat_Avancement_Physique_Reel	AC	BAC
Dec-21	0.01%	0.01%	995,217.39	9,156,000,000.00
Jan-22	0.32%	0.30%	29,856,521.74	9,156,000,000.00
Feb-22	2.10%	1.90%	189,091,304.36	9,156,000,000.00
Mar-22	5.54%	5.10%	507,560,869.59	9,156,000,000.00
Apr-22	7.52%	6.80%	676,747,826.12	9,156,000,000.00
May-22	9.43%	8.40%	835,982,608.74	9,156,000,000.00
Jun-22	13.59%	12.00%	1,194,260,869.62	9,156,000,000.00
Jul-22	16.68%	14.50%	1,443,065,217.46	9,156,000,000.00
Aug-22	22.31%	18.90%	1,880,960,869.66	9,156,000,000.00
Sep-22	25.86%	21.80%	2,169,573,913.15	9,156,000,000.00
Oct-22	30.98%	25.60%	2,547,756,521.87	9,156,000,000.00
Nov-22	34.93%	28.90%	2,876,178,261.01	9,156,000,000.00
Dec-22	37.12%	31.00%	3,085,173,913.20	9,156,000,000.00
Jan-23	39.36%	33.20%	3,304,121,739.29	9,156,000,000.00
Feb-23	41.61%	35.40%	3,523,069,565.39	9,156,000,000.00
Mar-23	44.70%	38.00%	3,781,826,087.14	9,156,000,000.00
Apr-23	47.51%	40.50%	4,030,630,434.98	9,156,000,000.00
May-23	50.76%	43.80%	4,359,052,174.13	9,156,000,000.00
Jun-23	53.59%	46.20%	4,597,904,348.05	9,156,000,000.00
Jul-23	55.24%	47.50%	4,727,282,608.93	9,156,000,000.00
Aug-23	56.67%	48.80%	4,856,660,869.81	9,156,000,000.00
Sep-23	57.96%	49.90%	4,966,134,782.85	9,156,000,000.00
Oct-23	58.95%	50.80%	5,055,704,348.08	9,156,000,000.00
Nov-23	60.55%	52.30%	5,204,986,956.78	9,156,000,000.00
Dec-23	62.00%	54.00%	5,374,173,913.31	9,156,000,000.00
Jan-24	64.59%	57.00%	5,672,739,130.72	9,156,000,000.00
Feb-24	67.14%	60.00%	5,971,304,348.12	9,156,000,000.00
Mar-24	71.04%	63.50%	6,319,630,435.10	9,156,000,000.00
Apr-24	73.40%	66.00%	6,568,434,782.93	9,156,000,000.00
May-24	77.02%	69.50%	6,916,760,869.91	9,156,000,000.00
Jun-24	77.97%	71.00%	7,066,043,478.61	9,156,000,000.00
Jul-24	80.13%	80.13%	7,974,460,351.64	9,156,000,000.00
Aug-24	81.57%	81.17%	8,078,124,766.84	9,156,000,000.00
Sep-24	82.25%	81.51%	8,111,727,713.47	9,156,000,000.00
Sep-24	84.89%	83.12%	8,272,557,190.49	9,156,000,000.00
Oct-24	91.18%	86.53%	8,611,222,549.94	9,156,000,000.00
Nov-24	96.85%	88.36%	8,793,765,953.33	9,156,000,000.00
Dec-24	100.00%	90.66%	9,022,640,870.01	9,156,000,000.00
Jan-25	96.66%	92.14%	9,169,933,043.93	9,156,000,000.00
Feb-25	100.00%	94.56%	9,410,775,652.64	9,156,000,000.00
Mar-25	100.00%	97.15%	9,668,536,957.00	9,156,000,000.00
Apr-25	100.00%	97.28%	9,678,329,020.30	9,156,000,000.00
May-25	100.00%	97.94%	9,743,992,025.57	9,156,000,000.00
Jun-25	100.00%	98.16%	9,765,879,694.00	9,156,000,000.00
Jul-25	100.00%	98.40%	9,782,732,371.92	9,156,000,000.00
Aug-25	100.00%	98.91%	9,833,435,558.00	9,156,000,000.00
Sep-25	100.00%	99.33%	9,875,191,123.00	9,156,000,000.00
Oct-25	100.00%	99.66%	9,902,752,099.50	9,156,000,000.00
Nov-25	100.00%	99.96%	9,932,561,708.47	9,156,000,000.00
Dec-25	100.00%	100.00%	9,936,536,323.00	9,156,000,000.00

APPENDIX F – PROJECT 3 DATA

RNS - Raccordement en EPC de quatorze(14) Puits cambro-	Etat_Avancement_Physique_Prevu	Etat_Avancement_Physique_Reel	AC	BAC
Nov-22	0.05%	0.37%	42,523,246.16	7,470,300,000.00
Dec-22	1.62%	0.73%	83,897,215.39	7,470,300,000.00
Jan-23	2.80%	0.82%	94,240,707.70	7,470,300,000.00
Feb-23	3.18%	1.59%	182,735,030.78	7,470,300,000.00
Mar-23	4.78%	3.21%	368,917,892.33	7,470,300,000.00
Apr-23	7.87%	3.71%	426,381,738.49	7,470,300,000.00
May-23	12.26%	7.75%	890,689,615.44	7,470,300,000.00
Jun-23	17.93%	9.14%	1,050,439,107.76	7,470,300,000.00
Jul-23	24.72%	12.27%	1,410,162,784.70	7,470,300,000.00
Aug-23	32.67%	15.35%	1,764,140,077.03	7,470,300,000.00
Sep-23	44.60%	17.27%	1,984,801,246.28	7,470,300,000.00
Oct-23	53.87%	21.85%	2,511,170,077.08	7,470,300,000.00
Nov-23	61.29%	25.69%	2,952,784,331.90	7,470,300,000.00
Dec-23	64.42%	27.68%	3,181,198,523.27	7,470,300,000.00
Jan-24	71.28%	29.91%	3,437,487,277.13	7,470,300,000.00
Feb-24	73.49%	39.44%	4,532,748,184.89	7,470,300,000.00
Mar-24	76.63%	43.72%	5,024,638,708.00	7,470,300,000.00
Apr-24	81.69%	47.26%	5,073,444,668.00	7,470,300,000.00
May-24	35.34%	42.98%	5,097,847,648.00	7,470,300,000.00
Jun-24	37.18%	44.59%	5,122,250,628.00	7,470,300,000.00
Jul-24	40.70%	48.18%	5,840,416,913.25	7,470,300,000.00
Aug-24	44.11%	50.46%	5,601,028,151.50	7,470,300,000.00
Sep-24	48.03%	55.14%	6,079,805,675.00	7,470,300,000.00
Oct-24	53.98%	59.57%	6,098,888,266.25	7,470,300,000.00
Nov-24	59.18%	64.04%	6,117,970,857.50	7,470,300,000.00
Dec-24	69.47%	66.18%	6,156,136,040.00	7,470,300,000.00
Jan-25	77.48%	68.53%	6,188,287,271.00	7,470,300,000.00
Feb-25	83.02%	70.74%	6,220,438,502.00	7,470,300,000.00
Mar-25	87.22%	72.69%	6,284,740,964.00	7,470,300,000.00
4/1/2025	92%	75.23%	5,950,000,000.00	7,470,300,000.00
5/1/2025	95.32%	77.40%	6,150,000,000.00	7,470,300,000.00
6/1/2025	98.20%	79.69%	6,350,000,000.00	7,470,300,000.00
7/1/2025	100%	81.83%	6,550,000,000.00	7,470,300,000.00
8/1/2025	100%	84.31%	6,750,000,000.00	7,470,300,000.00
9/1/2025	100%	86.21%	6,950,000,000.00	7,470,300,000.00
10/1/2025	100%	88.48%	7,150,000,000.00	7,470,300,000.00
11/1/2025	100%	90.50%	7,350,000,000.00	7,470,300,000.00
12/1/2025	100%	92.59%	7,550,000,000.00	7,470,300,000.00
1/1/2025	100%	94.50%	7,750,000,000.00	7,470,300,000.00
2/1/2025	100%	97%	7,950,000,000.00	7,470,300,000.00
3/1/2025	100%	100%	8,070,000,000.00	7,470,300,000.00