Master Thesis Report

Adapting Earned Value Management to Different Project Levels Based on Complexity

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By

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I earnestly hope that my research can bring benefits to the academic and practical world, while also allowing me to contribute further to the field of civil engineering.

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Executive Summary

The Construction Industry holds an important role by contributing around 6% to the Gross Domestic Product (GDP) based on data from Market Prospects. Despite this substantial contribution, numerous projects within the industry struggle to attain their objectives effectively. Project uniqueness, coupled with the impact of project complexity, leads to difficulties in project identification and inaccurate selection of control methods. Thus, appropriate project identification, control method selection, and monitoring techniques are vital to anticipating such issues. Earned Value Management (EVM) emerges as an advanced monitoring method to anticipate the issues that include scope, time, and budget as controlled variables within a project. However, there remains a research gap in how to effectively apply EVM to diverse project types to effectively monitor the project. Through this gap, therefore a research question emerges:

"How to adapt Earned Value Management to various levels of projects based on the project complexity?"

To answer this question, the study will first outline significant aspects within EVM and assess the maturity level of organizations implementing EVM. Van Oord is chosen as the study location to gather data on their EVM application. The study then delves into potential adaptations of EVM and its effective application across diverse project types.

As the methodology to answer the research question, this study starts with a literature analysis to define EVM and identify its influential aspects. The next step is conducting interviews with experts at Van Oord to understand their experiences and methods for controlling previous projects. These interviews involve 12 respondents, resulting in information of 17 different projects. The projects are then categorized into different levels and the information from these interviews are then categorized following the 10-step EVM model and ANSI/EIA-748 standard.

The research yields several significant outcomes. Firstly, the core EVM aspects are grouped under Earned Value Analysis, encompassing Planned Value (scope, budget, schedule), Actual Cost, and Earned Value. Project variance analysis, forecast calculations, and corrective action analysis are also recognized as critical components of EVM. The next step is understanding the organization maturity level, where this study reveals that EVM partially implemented at the selected projects, following the threshold of EVM Maturity Level standards.

The next step involves the formulation of frameworks. The ABCD EVM Framework is developed based on the modified EVM 10-step model, focusing on elements such as Earned Value Analysis and the ANSI/EIA-748 standard as modified EVM components. This study also reveals differences in EVM implementation among 17 projects categorized into 4 levels of ABCD project classification by Van Oord. One impactful aspect, as per the ANSI/EIA-748 Standard, involves determining the Work Breakdown Structure level, influencing the level of detail in schedule planning, budgeting, and progress tracking. Additionally, other variations include frequency of variance calculation and project forecast estimation. Various other aspects such as changes, responsibilities, reporting, and organizational decisions outlined in the discussion chapter are also differ on each project levels.

Moreover, the EVM framework is generated through TOE complexity analysis. Out of the 47 TOE Elements, 29 elements are being identified as influencing elements for the implementation of Earned Value Management. Projects are then grouped based on the project high score on each of these elements. By adhering to the scalability factor from the ANSI/EIA-748 Standard and considering interview outcomes, several suggestions are formulated for Earned Value Management activities. The objective is to anticipate the high-scoring TOE elements for each project. The EVM aspects influencing this framework mainly concern the Project Measurement Baseline Plan, Budget and Schedule Authorization, the level of detail in the Work Breakdown Structure, and the recording of allocation and management reports.

Conclusively, variation in the adaptability of Earned Value Management are shown in the resulted frameworks for variety of project levels, as well as becoming tools to improve the maturity level of an organization. For practical application, this study recommends organization to implement EVM using the project sizing classification approach while integrating insights from the TOE EVM Framework. This holistic strategy can enhance project monitoring and control across various complexity levels, contributing to the successful and effective outcomes of projects in the construction industry.

Keywords: Earned Value Management, Earned Value Analysis, Project Complexity, Project Classification, TOE Complexity, Van Oord.

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Abbreviation

GDP	: Gross Domestic Product
TOE	: Technical, Organizational, External
PMBOK	: Project Management Body of Knowledge
EVM	: Earned Value Management
CSF	: Critical Success Factor
BCWS	: Budgeted Cost for Work Schedule
ACWP	: Actual Cost for Work Performed
BCWP	: Budgeted Cost for Work Performed
PV	: Planned Value
AC	: Actual Cost
EV	: Earned Value
CPM	: Critical Path Method
NDIA	: National Defence Industrial Association
ANSI/EIA-748	: American National Standards Institute/Electronic Industries Alliance – 748
APM	: Association for Project Management
WBS	: Work Breakdown Structure
OBS	: Organizational Breakdown Structure
RAM	: Responsibility Assignment Matrix
RACI	: Responsible, Accountable, Consulted, and Informed Chart
C/SPCS	: Cost/Schedule Planning Control Specification
EVA	: Earned Value Analysis
CA	: Control Account
CV	: Cost Variance
SV	: Schedule Variance
CPI	: Cost Performance Index
SPI	: Schedule Performance Index
BAC	: Budget at Completion
EAC	: Estimate at Completion
SAC	: Schedule at Completion
CVAC	: Cost Variance at Completion
SVAC	: Schedule Variance at Completion
ETC	: Estimate to Complete
EVMS	: Earned Value Management System
SMART	: Specific, Measurable, Attainable, Realistic, and Time-Bound
EVT	: Earned Value Technique
PMB	: Performance Measurement Baseline

1. Introduction

1.1. Background

The construction industry is currently an important industry that contributes up to 6% of the Gross Domestic Product (GDP) which averages 5% of the GDP in developed countries and 8% of the GDP in developing countries (Market Prospects, 2021). Despite being a major contribution to the GDP, a lot of projects within the construction industry fail to achieve their objective successfully. Egan (1998) mentioned that in comparison to other industries, the construction industry has a low performance in terms of timeliness, budget, and customer satisfaction. Based on literature research, only 2.5% of the projects can be defined as completely successful with the scope, cost, and schedule according to the plan (Rivera & Kashiwagi, 2016).

The failures that occurred were not only in terms of time and cost but also several major accidents that resulted in the loss of life. Based on the surveys by NSC, since 2012, Construction Industry held the first rank as the most dangerous industry based on the number of deaths (NSC, 2021). The causes of the failures are various, such as poor management, planning, and risk assessment, where these aspects are the product of project complexity. In the concept of project, complexity is one causal factor determining the outcomes of the project, which in the terms of project management can be defined as a project success or failure factor (Montequín et al., 2018). Gidado (1996) and Kermansachi et al. (2016) define that complexity has a high influence on defining project success and failure, hence less information on project complexity or a higher level of complexity, creates a higher possibility of project failure. Additionally, there is no standard in defining project complexity yet, which sometimes project managers have their own methodology to define project complexity. A research by Owens et al. (2012), stated that some factors are established to define project complexity in different major projects in the U.S and these factors are mentioned separately in different projects (Miller, 2010; Majumdar, 2009; Migliaccio, 2008).

Complexity, however, can be identified and classified. Bosch-Rekveldt et al. (2010) mention a framework to define complexity which divided into three categories, namely the content of the project (T), the organizational view (O), and the environmental view (E). This TOE concept represented by 47 different elements which were obtained through multiple-case approaches and interviews to several different projects. In the actual project application, most common complexity found is because of lack of uniformity and standardization which creates bigger complexity (Bischoff et al., 2022). Cristóbal et al. (2018) on his research mentions that there are several ways to approach project complexity by placing them on several levels. Thus, by using mentioned frameworks, there is a big opportunity to prevent project failures by understanding the possibilities of project complexity and then a preventive action can be planned.

Deciding on the right project management method is an effort to reduce the possibilities of failure caused by complexity. One of the ways is to choose the correct project control and monitoring tools and modify it to adjust it to the level of project complexity that the project is. Project complexity has a strong influence on project control and monitoring since it can affect the objective, methodology, and even project outcomes, thus the more complex a project has, the more intense the controlling method should be (Bosch-Rekveldt, 2011; Cristóbal et al., 2018).

Project control therefore can be concluded as a very important aspect of a project. According to Project Management Body of Knowledge (PMBOK), controlling a project is an effort to maintain the project including the process of planning, measuring, monitoring, and taking corrective action (Rozenes et al., 2006). Project control besides preventing the possibility of an accident is also determining the success factor of the project (Syal & Duah, 2012). Frame (2003) states that project control makes projects effective with a time and cost approach. In addition, there are components of

risk control and mitigation in project control that are utilized to foresee uncertainties that are the products of complexity.

Project control, as mentioned earlier has the possibility to be modified. Some research done by Acebes et al. (2014) and Pellerin & Perrier (2018) mentioned that project control can be integrated and improved by using several control measurements. Control measurement is one of the tools that can be used as a parameter to integrate project control, for example, stakeholder management, interfaces, locations, project resources, quality, and execution targets (Kermanshachi & Nipa, 2021). Acebes et al. (2014) in their research, specify the use of Earned Value Management (EVM) as their example of integrating project control. The reason they choose EVM is that it is one of the controlling methods that has the possibility to be integrated. Although there are other methods of project controlling such as a simple method of comparing planning and actual budget or milestone trend analysis, EVM is the widely used and most advanced method since it integrates scope, time, and cost control in the same framework (Acebes et al., 2014).

EVM is a monitoring method for analyzing projects based on 3 important variables, namely the Budgeted Cost for Work Schedule (BCWS) which can be referred to as Planned Value (PV), Actual Cost for Work Performed (ACWP) or commonly called Actual Cost (AC), and Budgeted Cost for Work Performed (BCWP) or commonly called Earned Value (EV) (Warhoe, 2004). The concept of Work Breakdown Structure will be particularly used to determine the scope of the project and the use of Critical Path Method (CPM) and S-Curve as the form of time monitoring also used in EVM (Mayo-Alvarez et al., 2002).

Earned Value Management, although with the rapid spread and use is interpreted differently by each organization. The maturity level of the organization to apply EVM can be variate from not applying EVM at all to improving the system of the company's EVM (Stratton R. W., 2000). National Defense Industrial Association (NDIA) by their Integrated Program management Divisions setting guidelines through 32 steps of creating an effective Earned Value Management (NDIA, 2018). This standard can be used to determine the maturity level of an organization in the EVM, standard use of EVM, or even the EVM development.

The value set by these standards provides a great opportunity to be developed. Some development efforts have been done by several researchers to improve the EVM by developing its capability in evaluating the project, namely research done by Naeni et al. (2011), Navon (2005), Vanhoucke and Vandevoorde (2007), and Warburton (2011). NDIA (2020) also providing several suggestions on how to develop Earned Value Management by scaling the component of the EVM factors. However, the EVM following the objective of this method, should be able to be developed to control various type of project which can unravel the possibility of project failure due to complexity by using fit for purpose assurance or preventive action. Nevertheless, there is still no tailored connection between both of them.

Although the potential for EVM adaptation can be seen and project complexity can be classified into several levels, there is no research that discusses how to tailor both concept and make the EVM adaptable to various levels of project yet. This research aims to see if the possibility of the adaptation.

1.2. Research Design

As mentioned in the previous chapter, a research gap arises, which serves as the basis for this study. Then, in this chapter, discussions about the research objective, research question, and sub-questions, as well as the structure of this thesis report will be provided.

1.2.1. Research Objective

The goal of this research is to develop the adaptability of Earned Value Management to various levels of project based on project complexity by scaling the measurements or components of the Earned Value Management.

1.2.2. Research Question

"How to adapt Earned Value Management to various levels of projects based on the project complexity?"

Several sub-questions were formulated in order to answer the research question in greater depth.

1. **What are the significant elements in Earned Value Management?**
   This sub-question is important to determine the attributes that are important to perform Earned Value Management as a monitoring tool. The basic elements of EVM that are important to monitor projects will be the answer to this question. The methodology used to answer this question will be mostly through a literature review on EVM related to its elements, potentials, limitations and also some examples of its application.

2. **What is the maturity level of organization in applying Earned Value Management?**
   This sub-question is required to answer the state of the Earned Value Management application in the institution to which this EVM applies. By understanding their level of maturity, the institution may know to what extent they need to understand the concept of EVM before implement it.

3. **How can the application of EVM change based on the complexity of the project?**
   This sub-question is needed to see how the concept of earned value management can be modified or scaled by adjusting some of the constituent attributes. The objective of this sub-question is to see whether the significant elements in earned value management can be changed to follow the scope each project has, thus improving the functionality of EVM as a monitoring tool.

4. **How can EVM be practically adapted to different projects based on their level of complexity?**
   This sub-question is the conclusion to all sub-questions and will basically validate the research question. The possibilities of adaptability of the Earned Value Management should be seen by seeing the scaling factor on each of the Earned Value Management elements, also by validating the findings with experts who implement this concept. Moreover, the form of the framework to handle different project complexity measurement may also become the answer of this sub-question.

1.2.3. Research Scope

The scope of this project will be limited to only Earned Value Management as the basic monitoring concept. The starting concept is using the 10 EVM step model which was popularized by Sven Antvik (2012) whose dividing EVM into planning and implementation phase (Antvik & Sjoholm, 2012) and will be sorted into the concept of Earned Value Analysis provided by Reichel (2006) as the priority for development. The complexities will be limited by comparing the complexity which currently applied at Van Oord with the TOE complexity framework. The measurement used to classify the

complexity is using the approach of Earned Value Management standard of ANSI/EIA-748 (American National Standards Institute/Electronic Industries Alliance – 748), later it will be developed through the result of the interviews.

While the cases will be limited to the projects implemented by Van Oord and applied into 10 - 20 different projects to see the variety of project scope and complexity. For this study, the improved EVM framework will be focused on the planning and execution phase since it is the phase where most of the budget of the project will be used (Shahhossein et al., 2017), and also the phase where EVM will mostly be involved. During this phase also most of the resources will be used and also creating the highest possibility of project failures (Breesam, 2017).

1.3. Thesis Structure

This subchapter discusses the chapter and the topics that will be included in this report. Generally, this report will be divided into six chapters, including Introduction, Literature Review, Research Methodology, Results, Discussion, and Conclusion.

1. **Introduction**
   In this chapter, preliminary information will be thoroughly explained. It starts off by outlining the context and broad subject of this study. The gaps and problems are discussed in this chapter. This chapter will be divided into several subchapters which include Research Background which will be a summary of the introduction, literature review, and the research gap, and also later the research objectives will be stated.
   The research questions that will be raised in this study together with the sub-questions that will help answer the research question will be concluded. The last subchapter in this chapter is the scope as a limitation of this research.

2. **Literature Review**
   Some significant theories relating to project control, Earned Value Management, and project complexity will be discussed in this chapter. The outcomes of earlier research and their relevant discoveries will also be discussed. This chapter will also contain a few measurements and parameters that will be used in this research. The theoretical approach to the issues raised in the previous chapter will be discussed in more detail in this chapter. At the end, all of the theoretical findings will be summarized into several important points which become the source of the empirical study of this research. Furthermore, there will be also information about the framework table that determine what measurements are needed in the EVM for each level of complexity.

3. **Methodology**
   In this chapter, the method that will be used to answer the questions in the research questions will be explained. The method that will be carried out is data gathering through literature review, interviews and validation interviews. The validation mentioned will be through practical approaches as a source to improve the resulted framework.

4. **Results**
   This chapter will consist of all data gathered through the process mentioned in the methodology chapter that have relation to answer the objective of this research. The resulted maturity level, way to classify project, and the frameworks formed to manage the various projects based on their complexity are also discussed in this chapter.

5. Discussion

The findings of the study will be discussed in this chapter. The discussion will cover the results of the control measurements needed to develop the EVM based on references and interviews, and what measurements are needed to adapt the EVM to each level of project.

Apart from that, this chapter will also discuss the recommendation of implementing the results of this research to the construction industries in general. Lastly, this chapter will also consist the expert validation regarding the framework.

6. Conclusion

This chapter will mainly summarize all of the findings of this research. In this chapter also the research questions will be answered. Lastly, this chapter will be ended with some suggestions on what should be done by the next researcher or what is the potential future research to improve the content of this research.

2. Literature Review

This chapter will delve into relevant research theories. It will commence by elucidating project control and monitoring theory, followed by an exploration of Earned Value Management theory. This section will highlight the critical EVM aspect addressing sub-question number 1. Additionally, EVM maturity levels will be explained to tackle the second sub-question. The formulation approach of the EVM framework will also be detailed. Furthermore, the chapter will encompass discussions on various theories pertaining to project complexities. The conclusion of this chapter will tie together the correlation between the concept of Earned Value Management and project complexity. This connection will be illustrated through the preliminary framework, which will subsequently be refined through the completion of this research.

2.1. Project Monitoring and Control

A successful project is not only determined by the benefits for the client or organization involved but also determined by other success factors. Cost, time, and scope, which define the project's quality, comprise the "Triple Constraint" (Van Wyngaard, Pretorius, & Pretorius, 2012) which are the project success factors (figure 1). Other factors known as Critical Success Factors (CSF) determine the success of a project in addition to the triple constraint (Belassi & Tukel, 1996; Cooke-Davies, 2002; Kerzner, 2009). Alvarenga et al. (2018) identify at least 35 critical success factors that create the success of a project, with Project Monitoring and Control being one of the most frequently cited by academics.

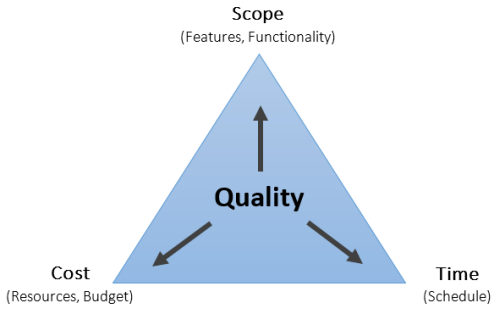


Figure 1 Triple Constrains in Project Management
Source: (Dhillon, 2018)

The APM body of knowledge defines project monitoring and control as an attempt to ensure that projects are executed properly. In a more specific definition, project monitoring and control is the application of project, programme, and portfolio management processes within the project framework to enable the organization to execute projects effectively (APM, 2006). Monitoring can also be defined as the process of collecting the completed information of a project using a performance matrix (De Marco, 2018). The process of monitoring a project, including the determination of performance to determine project variances.
However, project monitoring should be implemented following the completion of all project planning in order to control project execution. It creates a real-time comparison between actual progress and planned progress so that corrective action can be taken (Bennet, 1985).

Measuring performance is one method for determining whether the project control is operating effectively. In order to accomplish this, data collection must be precise and timely, which allows one to track the progress of the project. The project's status, progress, and forecast, including task completions in terms of percent complete, actual effort, and cost data/issues, will be useful reports (Shvartsberg, 2017). Ritz (1994) mentions in his research that Work Breakdown Structure (WBS) is also important for accurately measuring the progress of a project. WBS can serve as a representation of a detailed performance matrix that

accurately identifies and reports performance, as well as the project's responsible parties (Meredith & Mantel, 2006).

To track the progress of the project, supporting methodologies have been utilized as monitoring tools. The PMBOK® guide provides the basic foundation for monitoring, which consists of three essential steps: tracking, reviewing, and regulating the project's progress; identifying change areas; and initiating the changes. Therefore, the project manager can take certain actions, such as managing the project's scope, time, cost, quality, communication, risk, procurement, and integration (Hayes Munson, 2012).

Additionally, The project manager can also take several actions to keep the project on track when controlling the project. The methodology as shown in figure 2 are divided into performance-driven, in which the objective is to realign the project, and target driven, in which the contract can be modified if necessary to realign the project (De Marco, 2018).

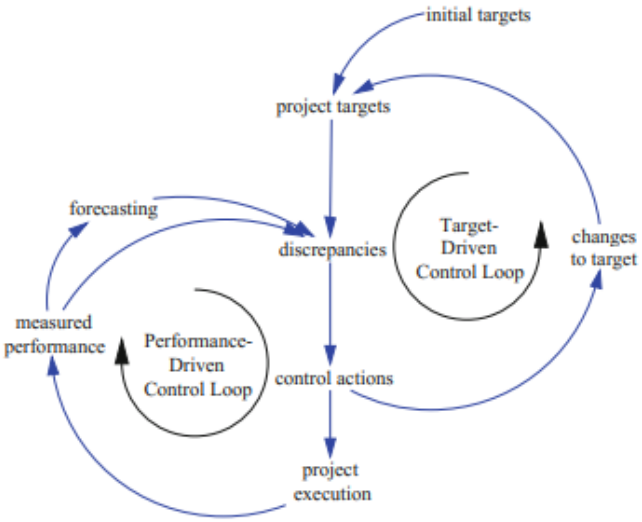


Figure 2 The Cyclical Process of Project Control Methodology
Source: De Marco, 2018

Typically, performance-driven control is implemented during the early phases of project development, when changes may have an effect on the project's performance. In order to keep the project on track, the project manager may implement corrective measures such as project crashing or resource reallocation. Alternatively, target-driven control may be implemented if the owner and contractor agree that unanticipated changes may render the target impossible to achieve.

2.2. Earned Value Management

As mentioned in the previous sub-chapter, monitoring and controlling a project can be accomplished using a variety of approaches and methodologies, including Budget vs Actual Comparison, Milestone Trend Analysis, Status Reports, and Earned Value Management (Roland Wanner, 2020). Earned Value Management (EVM) is, however, the most prevalent and advanced method.

Earned Value Management is a project management approach that utilizes planning, cost collection, and performance measurement (APM Knowledge, 2008). This method of control allows the project manager to evaluate the work performed based on reviews of cost and schedule reports. Using the measured progress, the project's completion date and total cost

can be estimated. This method is based on the earned value of the project (Reichel, 2006). EVM is also a tool that comprise the triple constraint including Cost, Time, and Scope. EVM is a control method that is based on a performance-driven strategy. The purpose of EVM is to monitor the project's progress on a periodic basis, providing the project manager with status updates so that corrective action can be taken (De Marco, 2018).

This system became known as the Cost/Schedule Planning Control Specification (C/SPCS) when it was introduced by the United States Air Force to mandate earned value in conjunction with planning and controlling requirements (Humphreys Associates, 2012). This concept has been evolving for decades until it was designed to adhere to the 32 EVMS standards published by the American National Standards Institute/Electronic Industries Alliance (ANSI/EIA-748) (Bembers et al., 2017; Humphreys, 2016).

EVM aims to establish a relationship between time-phased budgets and specific contracts; provides a foundation for capturing work progress and the connection to the baseline plan; generates technical, schedule, and cost performance; and provides managers with up-to-date data for decision making (Humphreys Associates, 2012). Wilkens (1999) notes that Earned Value possesses three characteristics: a uniform unit of measure for total project progress or sub-elements, a consistent method for analysing project progress and performance, and a basis for cost performance analysis.

2.2.1. Components of EVM

Basically, Earned Value Management has to be based on several fundamental steps in order to perform effectively, which are: the application of scope definition; defining the work breakdown structure (WBS) and organizational breakdown structure (OBS); budgeting in accordance with the WBS; scheduling; methods to measure achievements; spreading the budget over time; baseline the plan; record of the progress; analysis of the performance; forecasting; and incorporating all changes (APM Knowledge, 2008).

Reichel (2006) summarizes in order to applying Earned Value Management, five ground rules are required to be applied, which are: organizing the project team and scope of work, schedule the task in a logical manner; allocate the total budget resources to time-phased control accounts; establish objective means for measuring work accomplishment; control the project by analysing cost and performance variances assessing final costs; developing corrective actions and controlling changes to the integrated baseline. Moreover, Reichel also categorizes the critical element of applying Earned Value Management into Earned Value Analysis. Earned Value Analysis (EVA) is a method that can be conducted by a project manager to measure the amount of work performed by comparing and reviewing the cost and schedule report (as shown in figure 3). Lukas (2012) specified the concept of Earned Value Analysis into three key pieces of information which are Planned Value (PV or also known as Budgeted Cost of Work Scheduled (BCWS)) consist of scope, budget and schedule planned, Actual Cost (AC or also known as Actual Cost of Work Performed (ACWP)), and Earned Value (EV or also known as Budgeted Cost of Work Performed (BCWP)). A comprehensive grasp of these components can facilitate the implementation of Earned Value Management, which is characterized by the utilization of Variance and Performance Indexes to assess cost and schedule performance. The variances can serve as a valuable resource for conducting forecasting, estimating project completion (Estimate at Completion and Budget at Completion), and implementing corrective measures, if deemed necessary.

One important identity of Earned Value Management is having a structured activity detail into schedule presented by the application of the concept of Work Breakdown Structure (WBS) as

the project scope which included on the implementation of Planned Value. The work breakdown structure is a hierarchical subdivision of the project that divides the elements of the project into several levels. This breakdown continues until the lowest level of detail is reached for the visibility of management and control. Organizational breakdown structure (OBS) are generally the details of the people involved in the projects, which come from various functions and departments across a company. The breakdown is usually defined by a breakdown consisting of the roles and responsibilities that should be clear to all members of the project team. These two components were then combined into one control account (CA), which is a reflection of how the project has organized the people who are going to achieve the work. The assignment of work responsibilities is appropriate if the WBS is closely related to the OBS. The control account is the minimum application of system breakdown structure where comparisons between the planned budget and the actual budget are made (APM Knowledge, 2008). After the organizational aspect has been decided, the planning phase of the schedule and budget can be conducted following the details of the predetermined control account. Earned Value Management is one of the tools that can provide the status of the project and a clear objective analysis of it (figure 3).

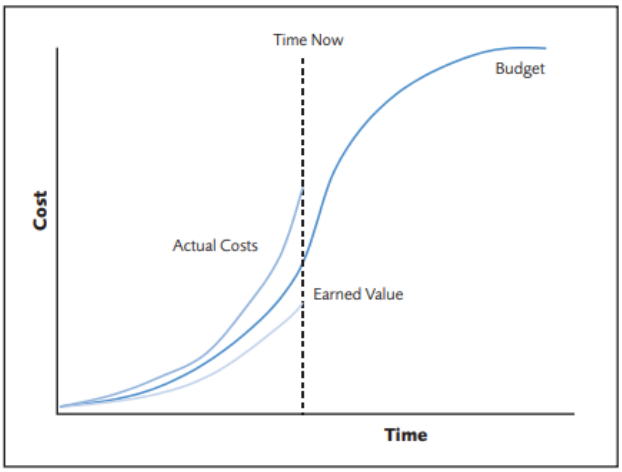


Figure 3 Earned Value Analysis Component
Source: (APM Knowledge, 2008)

In the application of EVM, Antvik (2012) summarizes a 10-step model of Earned Value Management application as a more elaborated Earned Value Management concept, this includes Project Goals, Project Budget, Project Scope or WBS, Schedule, Actual Cost, Earned Value, Responsibility Assignment Matrix (RAM), Organizational Breakdown Structure, Results and Deliveries, and Analysis on actions. Each of these attributes is implemented in a different project cycle. Based on Antvik (2013), planning project objective, project scope (WBS) planning budget, schedule, responsibility assignment matrix, and organization breakdown structure are implemented during the tender/planning phase, while recording actual cost, calculating earned value, reporting results and analysis on actions are implemented during the execution phase, which the concept of 10-step model will be further discussed later. This condition was also validated by NDIA (2018) on the ANSI/EIA-748 standard of project cycle in EVM applications. The aspects that need to be implemented during the tender phase are Project Authorization, WBS, OBS, Schedule, Planned Budget, and Performance Measurement Baseline.

2.2.2. Analysis of EVM

The fundamental elements can be combined to create a form of threshold as a determinant factor for whether the project is going as planned or not. Cost variance (CV) is a result of the calculation of Earned Value (EV) minus Actual Cost (AC), and the result if greater than 0 is favourable (underrun) and if it is less than 0 is unfavourable (overrun). Schedule Variance (SV) is a result of Earned Value (EV) minus Planned Value (PV), and the result if bigger than 0 is ahead of the planned schedule and if less than 0 is behind schedule (Humphreys Associates, 2012). The formula to calculate cost variance and schedule variance can be defined as follows:

$$\boldsymbol{SV = EV - PV} \tag{1}$$

$$\boldsymbol{CV = EV - AC} \tag{2}$$

Project overrun can also be detected by using the Cost Performance Index (CPI) by dividing EV by AC, where the result is on budget if it is equal to 1, under budget if it is more than 1, and over budget if the result is less than 1. Not only cost, but schedule delays can also be detected by using the Schedule Performance Index (SPI) by dividing EV by PV, and the result condition is on schedule if it is 1, ahead of schedule if more than 1, and behind schedule if less than 1 (Shvartsberg, 2017).

$$\boldsymbol{SPI = \frac{EV}{PV}} \tag{3}$$

$$\boldsymbol{CPI = \frac{EV}{AC}} \tag{4}$$

The variance thresholds are recommended to be settled. This threshold can provide guidance on the minimum variance that the project manager needs to keep for bring to the project. If variances fall outside the threshold, management needs to take action on how to keep the track back on plan. This threshold can be monitored by using a bullseye chart (Figure 4), which shows the movement of SPI and CPI within some period of time. Aside from using the bullseye chart as a tool to monitor changes in variances, the SPI/CPI performance graph is commonly used. This graph shows the movement of variance, which is shown by the changes of SPI and CPI within time and also potential variances at completion time.

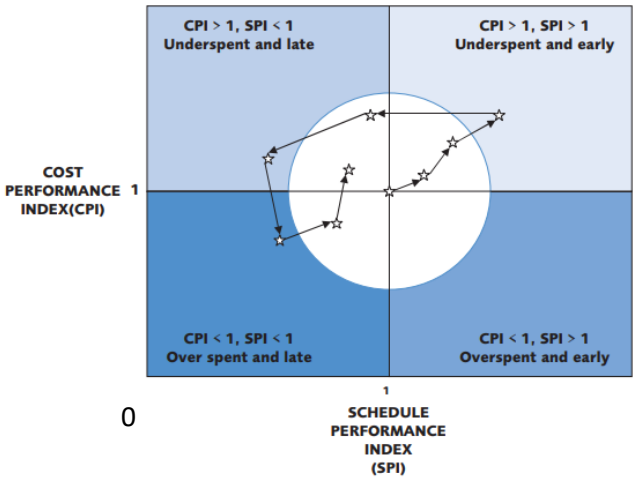


Figure 4 Bullseye Chart
Source: (APM Knowledge, 2008)

Earned Value Management, aside from its function of knowing the current status of the project, can also help to forecast the completion of the project. The forecast can be applied to both schedule and cost at completion. Some terms used in forecasting completion in terms of cost are Budget at Completion (BAC), Estimate at Completion (EAC), and Cost Variance at Completion (CVAC), while for schedule, they are Schedule at Completion (SAC), Estimated Schedule at Completion (ESAC), and Schedule Variance at Completion (SVAC) (Shvartsberg, 2017).

Estimate at Completion can be calculated at the level of WBS or OBS with the following formula:

$$\boldsymbol{EAC = AC\ Cumulative + ETC} \tag{5}$$

The formula above applies when remaining work is re-estimated and the baseline is no longer relevant. Estimate to Complete (ETC) is the estimation of the cost of work that is not yet completed. Several considerations need to be made in deciding the ETC, such as the validation of the estimate of the work. Since there are many algorithms, consistency and accuracy in data reporting need to be maintained to make the forecast more accurate (Warhoe, 2004). This formula is the most generic use for estimating project completion. Besides the formula above, there are some other formulas that can be used to predict the EAC, such as:

$$\boldsymbol{EAC = \frac{BAC}{CPI}} \rightarrow \text{When current performance continues to the remaining work} \tag{6}$$

$$\boldsymbol{EAC = AC + (BAC - EV)} \rightarrow \text{If the remaining work will be performed as planned} \tag{7}$$

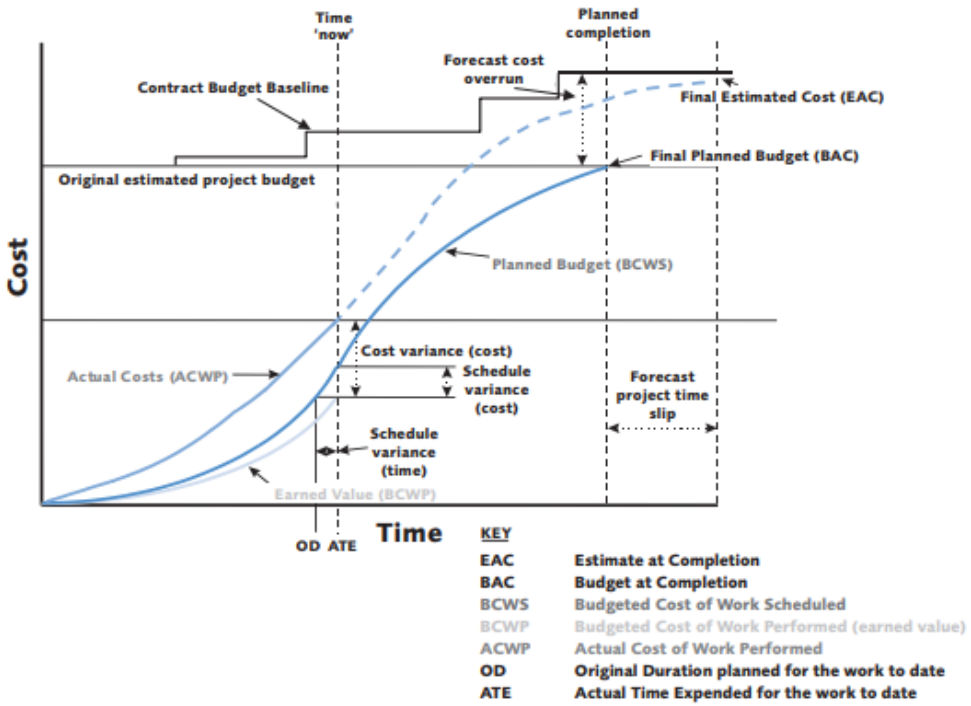


Figure 5 Complete Graph of Earned Value Management
Source: (APM Knowledge, 2008)

Figure 5 showing the complete definition of all measured elements in Earned Value Management. These elements may become a useful source for detecting problems or delays in the project, which detected by the resulted project variances. These variances may result in changes to the project plan, but the ultimate decision regarding whether to completely change the objective or take corrective action lies with the project client or other responsible parties. Corrective actions are the steps taken by project managers to remove the cause of an unanticipated and undesirable situation, with the goal of also identifying the cause in order to use it as the basis for future project evaluation (Tashi, Mbuya, & Gangadharappa, 2016; Shvartsberg, 2017). Shvartsberg (2017) provides the project manager with several corrective actions based on his research. The corrective actions available are divided into two categories: schedule slippage and budget overruns.

- Schedule Slippage
  Schedule slippage or project schedule overrun is a condition in which delays in a project occur for a variety of causes. PMI (2018) has compiled a list of primary causes of project failure that contribute to project delays. The majority of causes were due to a change in an internal aspect of the project, such as the organization or the project's objective. Inaccuracy and poor management are the least significant factors.
  Several corrective actions can be taken for schedule slippage, including Crashing by adding sources or working hours; Fast-tracking by changing the sequence of tasks; Maximizing the use of resources; Employing the most advanced technology; and reducing the scope (Shvartsberg, 2017).
- Budget Overruns
  Overruns in a project's budget can be defined as an increase in actual costs that exceeds the original estimate (Invernizzi, Locatelly, & Brookes, 2018). According to the research of Abusafiya (2017), the most common causes of cost overruns are frequent design changes, schedule delays, and construction errors. (Abusafiya, 2017)

Some actions that a project manager can take include substituting cheaper materials or adjusting agreements with suppliers; exploring the possibility of doing a trade-off with the client's approval by reducing the project's scope or delaying its completion; and finally, increasing the productivity of the staff. (Shvartsberg, 2017).

2.2.3. EVM Maturity Level

Project organizations have varying levels of experience and skill in managing projects and implementing project management principles. Project management maturity level refers to the extent to which an organization applies project management to a project (Aramali et al., 2023). Aramali et al. (2022) compiled at least 11 distinct maturity models used in project management over the past two decades, whereas Yussef et al. (2012) evaluate well-defined project management elements across five maturity levels. According to the research of Kerzner (2009), there are 16 factors that lead to project maturity.

EVM maturity level can be defined as the extent to which an organization has implemented the Earned Value Management system in its system, process, and deliverables (Aramali et al., 2022). Gareis and Huemann (2000) in using a spider-web presentation as the maturity levels, Crawford (2001) in using a five-level model of project maturity, and Andersen and Jessen (2003) in using a three-level ladder for maturity all reached similar conclusions regarding the significance of the visual representation of maturity levels.

The research conducted by Aramali et al. (2023), who interviewed 36 EVMS industry experts and 56 EVMS practitioners, demonstrates the significance of the EVM maturity attribute and its ability to be defined and measured. However, after reviewing multiple journals, only one model explicitly scales the level of EVMS maturity. Stratton (2006) developed a model in which the maturity level of an EVM is determined by its conformance to the ANSI/EIA-748 EVM standard.

Stratton (2006) classified EVM maturity into five levels, with each level representing the organization's comprehension and implementation of EVM. The levels can be described in the following manner:

- Level 1: Initial Level
  At this level, the organization uses a very limited EVM as their monitoring tool, or even no EVM at all. Organizations at this level are usually in the phase of developing EVM as their control system for a few of their projects as samples.
- Level 2: Partial Implementation
  Organizations at this level started to implement EVM by following the standard ANSI/EIA-748, which is sufficient to handle a small-scale project. However, not all significant elements of EVM have been implemented, usually limited to the use of planning and scheduling, maintaining the performance baseline, and monitoring the project's performance. Positive results will increase the opportunity for investment to improve to a higher maturity level.
- Level 3: ANSI/EIA-748 Compliant Implementation
  This level is indicated by the ability of the management team to use all data related to the EVM. The control account also has the ability to compare the schedule and cost objectives using the SPI, CPI, and other analyses in EVM.
- Level 4: Managed Implementation
  In level 4, additional measurements are used to assess the quality of the EVM. An assessment using metrics is conducted to see the opportunity for further improvement in the EVM system. In addition to the system, a training program to increase the

awareness and knowledge of the staff about the EVM also conducted by the organization, especially to produce a recorded repository for the EVM update.

- Level 5: Optimizing Implementation
  This is the highest level of EVM maturity. Organizations that have reached this level are using EVM as their daily standard of project monitoring tools, and monitoring on the system is regularly conducted to see the possibility of improvements.

Clear distinction of EVM maturity level can be seen on Table 1, which mentioning several criteria that identifying the condition of one organization level of maturity (Stratton R. W., 2006).

Table 1 EVM Maturity Criteria

Category	Level 1	Level 2	Level 3	Level 4	Level 5
Use of EVM Concept	No or very limited Earned Value Management	Earned Value Management data for whole project	ANSI/EIA-748 Criteria	Earned Value Management process group	Earned Value Management system improvement projects
Components of EVM Used	Occasional use at the team level	CPI and SPI for total project	Material, Indirect costs, and subcontractor costs	Earned Value Management System (EVMS) EVMS performance data	Earned Value Management system improvement project reporting
	Frequent re-baseline and poor planning	Direct costs are reported in staff-hours or dollar	Control accounts and control account managers	Earned Value Management system training	Earned Value Management system quality manager
EVM Organization	Limited value	Limited value	WBS and OBS integrated with cost and scheduling systems	Earned Value Management library	Earned Value Management library

2.2.4. EVM 10 Step Model

Antvik and Sjöholm (2012) define in their book that a basic EVM needs to have 10 important steps to be applied in the project (Figure 6). These steps are a streamlining narrative of applying Earned Value Management to a project from start to finish. The process is divided into two phases: the planning phase, consisting of six steps, and the implementation phase, consisting of four steps (Georgy & Dionysios, 2014).

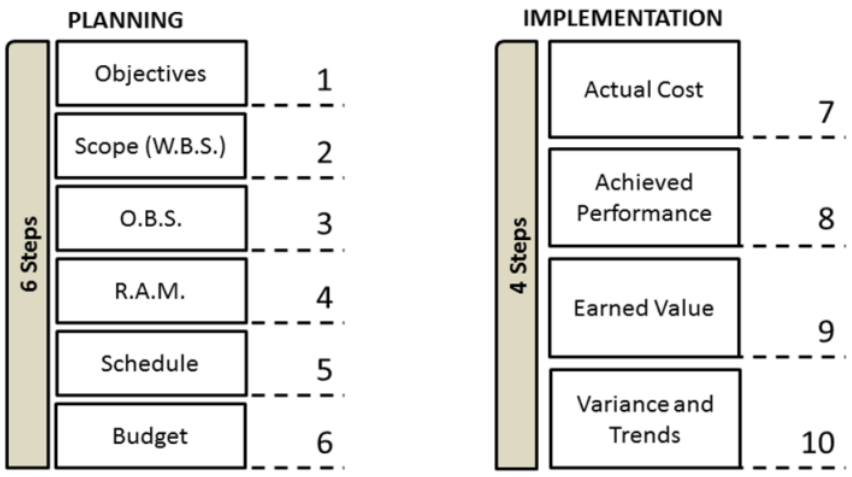


Figure 6 10-steps model of EVM
Source: (Georgy & Dionysios, 2014)

a. Objectives

The project's most important aspect is its objectives. It specifies the project's objective, timeframe, and budget. Generally, a good project objective applies strategy to the project and employs the SMART methodology (Specific, Measurable, Assignable, Realistic, and Time-Bound). The SMART concept explains that an objective should be specific, have a measurable indicator, be assignable to an individual, be feasible to implement, and have a timeframe for completion (Doran, 1981).

b. Scope (Work Breakdown Structure)

Work Breakdown Structure (WBS) can be defined as a hierarchical subdivision of a project that is divided into some discrete elements of work (figure 7). Warhoe (2004) defines work breakdown structure as a systematic approach to taking the scope and placing it in a hierarchic organization. Yonezawa (2005) mentions in his research that project scope must be clearly included in the WBS. Integrated schedule and cost management, and a work package that determines the measurement of project performance also need to be part of the WBS. Later on, the work package can be assigned to the activity level for project monitoring and control, which will be defined at the lowest level of the WBS.

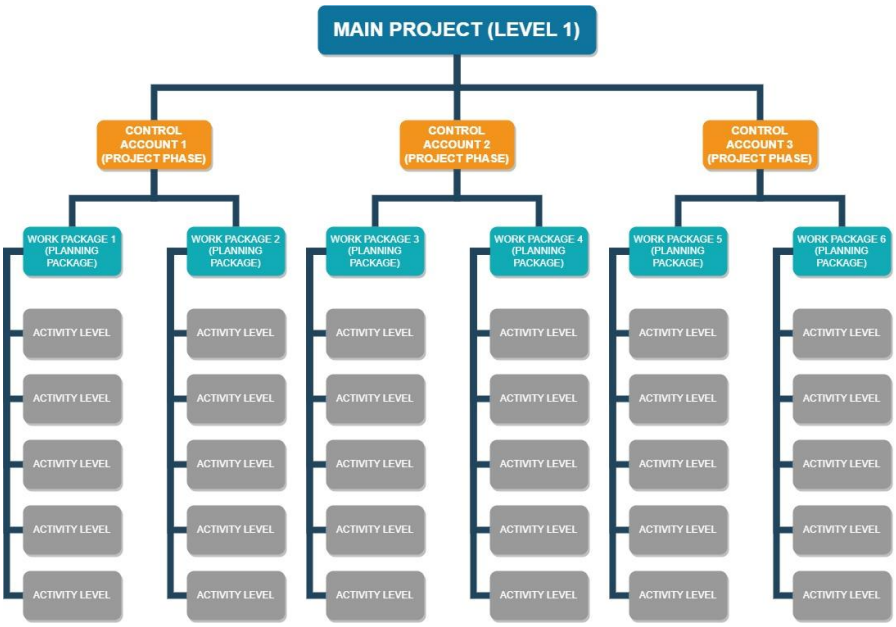


Figure 7 Example of Work Breakdown Structure Application

WBS comes in levels, where the descending level represents increasingly detailed information and definitions of project components (products or services). Level 1 defines project goals and identity, level 2 defines project phase (project manager level), level 3 about the work package level (planning package), and level 4 defines the activity level (PMI, 1996). Beside the levels, WBS also comes with a dictionary, which consists of contract numbers, WBS numbers and dates, contract paragraph numbers, and a statement of work including all contract deliverables (APM Knowledge, 2008).

c. Organization Breakdown Structure (OBS)

Similar to WBS, OBS is a tool in the form of a chart that defines the roles, responsibilities, and accountabilities of all staff involved in the project (APM Knowledge, 2008). Levine (1993) defines the objective of OBS as the accumulation of all timing, resource data, and costs in the project for which the organizational

entity is responsible and also related to administrative budgeting within the organization.

d. Responsibility Assignment Matrix (RAM)

The Responsibility Assignment Matrix is an integration between WBS and OBS that displays the segment of work and who is responsible for the activity. The RAM can be identified as a control account where it becomes the responsibility of management to plan the authorized work, perform performance measurement, and collect reports (NDIA, 2018). RAM can also be called the RACI Chart (Responsible, Accountable, Consulted, and Informed Chart), which spells out the roles of all stakeholders involved in the project (Friedman, 2008).

e. Schedule

APM (2008) defines schedule as the process of determining when all project activities occur based on the project's duration and preceding activities. In relation to WBS, a schedule may be broken down from the highest-level plan to the work package activity level. All contractual milestones must be included in the schedule that are linked to the activities; therefore, the schedule will be influenced whenever a change occurs.

Consideration of the critical path is the first step in developing a project schedule (figure 8). Critical Path Analysis is defined by Walker and Kelley (1989) as the path of a project that is the longest and, consequently, has the lowest tolerance for slippage. In their research, Khare et al. (2019) divided CPM into six steps, including the use of WBS to define the activity, creating the sequence, forming the network diagram, assigning an estimate to each activity, identifying the critical path, and creating the critical path diagram to illustrate project progress.

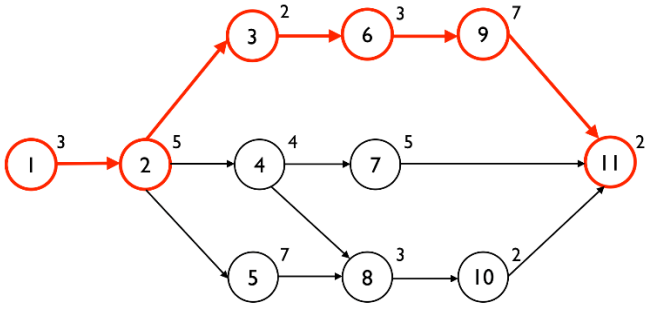


Figure 8 Example Diagram of CPM
Source: (APM Knowledge, 2023)

f. Planned Budget

Budget or planned value is the sum of all work package budgets that are scheduled to be completed within a given time period. APM Knowledge (2008) defines planned value as the schedule for spending budgeted resources to achieve project objectives. Planned value is defined by Narvaez et al. (2022) as an indication of the approved budget for work scheduled to be completed by a specific date.

According to the NDIA's (2018) recommendations for implementing Earned Value Management, the project budget should be derived from the level of control accounts, which includes labour, subcontract, material, tools and equipment, and any other direct costs. The established budget must also be planned by element in cost that is defined by measurable units and appropriate rates, in addition to a budget for planning the work, indirect budgets for facilities and other operational costs, and an undistributed budget for risk and management reserve.

In performing the estimation of project budget planning, there is a concept of budget estimation which summarized in the Cost Estimate Classification System (AACE,

2005), where the process of estimating project budget is divided into several phases. For each phase, distinctions are made based on project-specific information and its implementation in the project tendering process. For the specifics of each classification, they can be seen in the table 2.

Table 2 Cost Estimate Classification Matrix

	Primary Characteristic	***Secondary Characteristic***			
ESTIMATE CLASS	**LEVEL OF PROJECT DEFINITION** Expressed as % of complete definition	**END USAGE** Typical purpose of estimate	**METHODOLOGY** Typical estimating method	**EXPECTED ACCURACY RANGE** Typical variation in low and high ranges [a]	**PREPARATION EFFORT** Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

This matrix is useful for assisting organizations in estimating projects during the tendering phase. Class 5 and 4 estimations are typically performed when project details and certain aspects of the project have not been identified, while for projects with identified project details, they fall within classes 3 to 1.

The type of information held within the project also determines Cost Estimation, where in the matrix, for post-awarded project applications marked by a clear contract, Cost Estimation levels 3 and above can be used. As shown in Table 3, several requirements must be possessed to carry out this estimation. This information is mostly related to site conditions and Earned Value Management components.

Table 3 Estimate Classification Requirements

	ESTIMATE CLASSIFICATION				
General Project Data:	**CLASS 5**	**CLASS 4**	**CLASS 3**	**CLASS 2**	**CLASS 1**
Project Scope Description	General	Preliminary	Defined	Defined	Defined
Plant Production/Facility Capacity	Assumed	Preliminary	Defined	Defined	Defined
Plant Location	General	Approximate	Specific	Specific	Specific
Soils & Hydrology	None	Preliminary	Defined	Defined	Defined
Integrated Project Plan	None	Preliminary	Defined	Defined	Defined
Project Master Schedule	None	Preliminary	Defined	Defined	Defined
Escalation Strategy	None	Preliminary	Defined	Defined	Defined
Work Breakdown Structure	None	Preliminary	Defined	Defined	Defined
Project Code of Accounts	None	Preliminary	Defined	Defined	Defined
Contracting Strategy	Assumed	Assumed	Preliminary	Defined	Defined

g. Actual Cost (AC)

Actual Cost in terms of Earned Value Management is the actual cost of the work accomplished (APM Knowledge, 2008). Actual Cost is defined by Chen et al. (2016)

as the cumulative actual cost as a continuous or periodic sum of the budget used to complete work to date.

Christensen (1999) mentions that when defining the Actual Cost, a similar approach to the planned value must be taken, including the recording of both direct and indirect costs. In addition, Actual Cost must be recorded in the same time period as the Earned Value for each project activity so that comparisons can be made with clarity (Christensen, 1999).

h. Achieved Performance/Report and Deliveries

This activity related to the effort done to check the progress of the project. This achievement should be regularly reported in the progress report (daily, weekly, or monthly report). Also in the report, the actual progress of activity need to be specifically mentioned, so the project manager can take action if there is schedule slippage or cost overruns.

Activity definition also plays important role in deciding if the activity has been achieved. The project manager will easily decide if the activity has been done if only the activity is detailed in terms of sequence and having clear definition of the objective of the activity (Zwikael, 2009).

i. Earned Value

Chen et al. (2016) define earned value as the cumulative earned value in a continuous or periodic sum of the approved budget for work performed to date. Reichel (2006) defines earned value as the worth quantification of the work done to date.

There are several ways to measure earned value, known as earned value techniques (EVT). The EVT should be assigned to the level of work package, which is consolidated through the WBS and OBS up to the total project level. The measurement, however, needs to be taken at the lower level of the project. Several methodologies can be used, such as (APM Knowledge, 2008):

- Milestone Complete : Achievement of work defined by the milestone of the activity. The milestone can be measured by the earned predetermined proportion budget towards the activity.
- Percentage Complete : This activity usually applied to a project where an objective to determine percentage of work package exist.
- Equivalent Units : This method is simply done by comparing the items that have been used with the actual results that has been achieved. This method usually used in a manufacturing industry.
- Formula Method : Formula on Earned Value applied in this methodology. This formula (shown in formula 8) is usually used in a project where progress can be directly related to spend and useful to update the EAC to be more accurate.

$$EV = AC\ x\ BAC/EAC \quad (8)$$

- Level of effort : This measurement method usually used to measure project activity that does not have a specific product or end result, therefore the passage of time used as the measurement tools.
- Apportioned effort : Apportioned Effort is a measurement tool that is not easily be able to be divided into short package, instead it is dependent to the completion of the predecessor package.

j. Analysis (Variance and Trends)
Calculating project variances is one of the analysis parts of using Earned Value Management. NDIA (2018) suggests that at least this activity can be conducted on a monthly basis to support the project manager in assessing the deviation occurring during that time period, and the deviation in the performance measurement baseline will be visible. Then, the project manager can take corrective action to bring the project back to plan. One important thing is that all data needs to come from the same source, which is the measurement of Earned Value Management (PV, AC, and EV), and also be processed and restored in a standard and consistent accounting system.
Estimated at Completion (EAC) will be the product of this activity. Management can see the finish line of the project and how much they have to spend until it is finished. This is the main aspect of using Earned Value Management, where the forecasted finished project can be visible.

2.2.5. NDIA Standard Model

Application of Earned Value Management requires several important attributes to become useful to monitor and control a project, at least the 10-step model introduced by Antvik and Sjöholm (2012). However, the National Defence Industrial Association (NDIA) Integrated Program Management Division, which introduced the concept of Earned Value Management, made a standard for Earned Value Management systems using the EIA-748-D Intent Guide, which is also used by the Project Management Institute as their EVMS standard. ANSI/EIA-748 is a standard that has proven to provide strong benefits for planning and control (NDIA, 2018). This standard consists of scope definition, schedule and cost, plan, and plan to accomplish an objective of a program, using earned value as a measurement of project performance during the execution of a project (Schulte, 2000).

The ANSI/EIA-748 guide consists of five major categories, with each category determining the important steps and principles for using an integrated Earned Value Management system (Figure 9). The details and definition can be found at Appendix B about ANSI/EIA-748 guideline of Earned Value Management application.

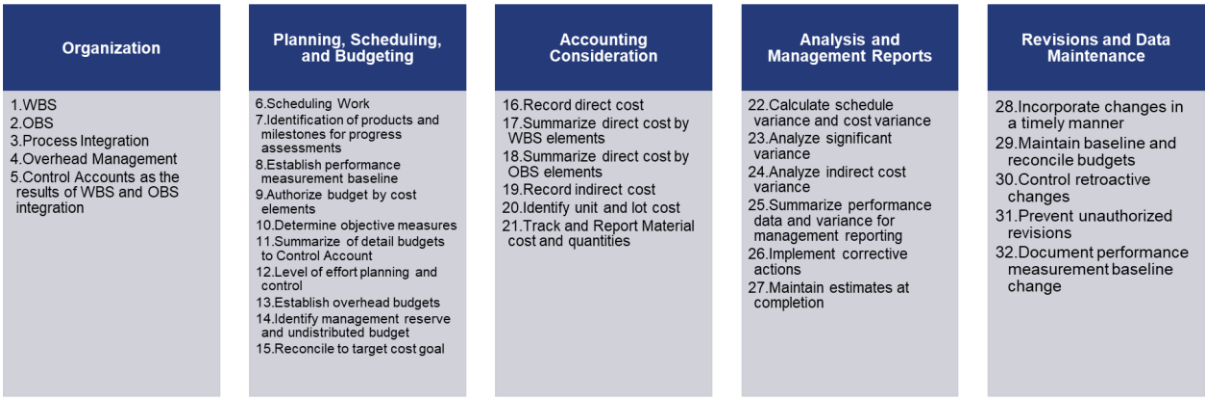


Figure 9 ANSI/EIA-748 EVM Steps
Source: (NDIA, 2018)

In terms of applicability, as shown in Figure 10, each attribute has a suggested project phase in which it should be implemented. In general, Earned Value Management application consists of two phases: the Implementation Phase and the Execution Phase. The Implementation Phase is the initial phase of the project or the planning phase, and the

Execution Phase is the project phase where the controlling and analysis methods play a greater role (NDIA, 2018).

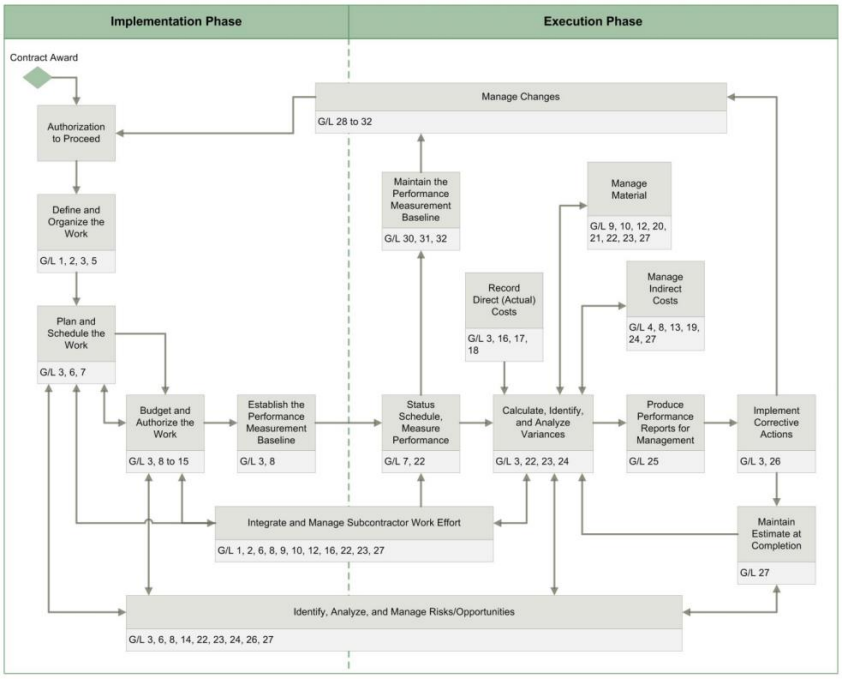


Figure 10 ANSI/EIA-748 EVM Phase
Source: (NDIA, 2018)

2.2.6. Possible Development of EVM

Since its introduction, EVM has been utilized in numerous examples of project applications, which have been modified multiple times to accommodate the project's circumstances. EVM has been utilized in the federal government and commercial sector of the United States (Garrett, 2006). It has been utilized not only in the construction industry, but also in information technology (Pratt, 2006). Nkiwane et al. (2016) mention that there is correlation of developing EVM by increasing the project management maturity level.

Ngo et al. (2022) investigated efforts to reformulate EVM using a singularity function strategy. The development is accomplished by analysing the exchange of metric axes and the changes in the data recording period. Hendiani et al. (2020) conducted research to improve the accuracy of cost-duration tracing in Earned Value Management by conducting a probability modelling analysis.

Acebes et al. (2020) discovered that development can also result from EVM system components. Integration of project schedule management can be developed to create Earned Duration Management (EDM), where the value of activities is based on work period, whereas Earned Value Management (EVM) typically uses budget as the monitored variable. Batselier and Vanhoucke (2015) evaluated the precision of EVM as a tool for project completion forecasting. Wauters and Vanhoucke (2015), on the other hand, use computational experiments to maintain the stability of the project's results, which aids in estimating the final project duration.

In addition, aspects that can be developed within the Earned Value Management concept are the characteristics of each component. According to NDIA (2020), Earned Value Management has the possibility of being scaled by modifying some of its constituent components. Several elements and attributes in Appendix C can be modified to accommodate the specifics of the project being worked on.

This attribute component consists of nine chapters, which are:

- Organizing Project Management, related to project scope and breakdown structure.
- Developing and Maintaining an Integrated Project Schedule in relation to the planning schedule method.
- Defining Budgets and Authorizing Work in relation to budget planning.
- Interfacing EVMS with the accounting system for recording and updating actuals.
- Managing and utilizing Project Performance Information related to the project's variance analysis and corrective action.
- Incorporating Approved Changes Into the Project which relates to the role change mechanism.
- Managing Project Material Items pertaining to the project's sources and resources.
- Managing Subcontracted Work Effort if work is performed by subcontractors.
- Managing Indirect Budgets and Costs as part of project budget planning.

This standard has the possibilities to be used as the scaling baseline, so the scalability will be specifically impactful to the application of Earned Value Management. For example, in the EVM 10-step model method, there are several aspects that can be scaled according to the standards set by NDIA (2020). The potential aspects that can be further developed within each component of the 10-step model can be observed in the table 4.

Table 4 Scaled EVM Aspect in 10-Step Model

10 step model	Definition and Aspect	ANSI/EIA-748 Standard Guideline for Scaling
Project Goals	Definition of the task or goal that the project aims to fulfil	Non-Scalable
Work Breakdown Structure	Structured breakdown of all task and activities that shall be carried out in the frame of the project	Defining the Work Breakdown Structure Levels
Organization Breakdown Structure	Structure break-down of all parties involved in the project execution	Establishing of Project Organization
Responsibility Assignment Matrix	Responsibilities of activities in project such as reporting chain and procedures	Communication Chain
		Handling Subcontractor
		Taking Corrective Action
Schedule	Planning of activities, deliveries and milestones, critical chain	Integrating Schedule Content and Requirements
		Integrating Schedule with the WBS and OBS
		Structuring Schedules for Progress Status and Forecast
Planned Budget	A plan for the project budget and its spending over the project execution time	Authorizing Work Scope and Budget for Resources
		Planning Resource Budgets for Future Effort
		Planning Resource Budgets for Non-Measurable Effort
		Creating Holding Accounts for Work Scope and Budget (Management Reserve and Undistributed Budget)
		Ensuring Proper Allocation of Indirect Budget in the Performance Measurement Baseline
Actual Cost	The actual cost of manpower and material, as invoiced during project execution	Ensuring Actual Costs are Comparable to Project Budgets
		Ensuring Accounting System for Materials and Interface Supports Project Management Needs
		Updating on financial condition period
Results/Deliveries	Checking which activities are fully completed (regular basis)	Regulation of Changes (Change in Performance Measurement Baseline)
		Preparing Summarized Information for Management

10 step model	Definition and Aspect	ANSI/EIA-748 Standard Guideline for Scaling
		Evaluation (Report Information)
		Reporting Indirect Cost
		Reporting Subcontractor Activity
Earned Value	Compilation of the budgeted value of the activities that have been completed up to date	Providing Performances for Project Analysis
Analysis	Efficiency of the work processes	Tools to support changes
		Analysis on Variances level
		Evaluating and Updating Estimates at Completion

2.3. Project Complexity

This chapter will discuss the theory of project complexity used in this research. Project complexity is one important aspect that helps to identify the project characteristic. In this research, the definition of project complexity will be divided into the definition of complexity in general, project complexity measurement, and the TOE concept that gathered several common causes of project complexity.

2.3.1 Definition of Project Complexity

The majority of project failures are due to either an unpredictable event or a predicted event with poor management, uncertainty, lack of planning, poor risk assessment, organization, or limited resources, all of which are the component of complexities (Shahriari & Catherine, 2015; Khaled, 2019; Afshar, 2017; Rivera & Kashiwagi, 2016; Mahamid, 2016; Abbasi et al., 2014; Pinto & Mantel, 1990).

Complexity is a crucial aspect that must be comprehended in order to determine the optimal method for evaluating the project. According to Gidado (1996) and Kermansachi et al. (2016), complexity has a significant impact on the success of projects and can therefore be classified as a project success factor; consequently, the higher the complexity of the project, the greater the likelihood that it will fail. Failure of a project in terms of delays and cost overruns can also be attributed to an increasing level of complexity or an underestimation of the project's complexity; however, complexity is still treated as a black box, with the exact factors that cause complexity remaining unidentified (Bosch-Rekveldt et al., 2010).

There is no precise definition of project complexity because the term can have different meanings depending on the organization's perspective and by the principal that every project is unique (Sinha, Thomson, & Kumar, 2001). According to Parwani (2002), complexity is the study of complex systems, which, due to their complexity, have no universally accepted definition. Despite the ambiguity surrounding the definition of project complexity, it can be understood as the properties of a project that make it distinct, unique, and difficult to comprehend. Even though complete information about the project system is provided, these obstacles make it difficult to predict and manage the project (Vidal, Marle, & Bocquet, 2010). According to Whitty and Maylor (2009), a complex project should include dynamic, structural, and interaction elements. (2009), (Whitty & Maylor).

Several factors can help define the complexity of a project. Maylor et al. (2008) compiled several findings about complexity adapted from the literature on project management. Organizational complexity, resource complexity, and technical complexity are described in detail. Complexity can be defined as structural uncertainty and uncertainty in terms of goals and method (Williams, 1999); complexity can also be defined as interdependence between physical elements of a project (Baccarini, 1996); or as the combination of structural and dynamic elements of organizational and technological aspect in a project (Xia & Lee, 2004).

Another piece of research by Owens et al. (2012) identifies factors that, either independently or combined, contribute to project complexity. These factors are categorized based on an area related to project management. The area and the factors are described as follows:

- Cost factors: Estimation, cost allocation, cost control, materials, contingency, and uncertainties.
- Schedule factors: Time, risk, control, optimization, control, resource availability, and supporting technology.
- Design factors: Scope, organization structure, delivery method, methodology, health/safety, quality, climate, and optimization.
- Context factors: Social equity, global economic condition, public condition, politics, demographics, land use and acquisition, sustainability, environmental, law, weather, and force majeure.
- Finance factors: Transition, uniformity, financial skills, state, bond, public-private-partnership, and global participation.

2.3.2. Project Complexity Measurement

There is no specific method for measuring the complexity of a project because complexity itself lacks specific details and a precise definition. Every project is also unique with its own variety and identification, thus there is no one specified method to categorize a project. Despite the uncertainties, project complexity can be identified using several approach, allowing for the selection of an appropriate tool to manage the complexity.

This section will describe a typical method for measuring the complexity of a project. These measures, such as the comparison analysis and the TOE concept, are very useful for mitigating potential project risks.

2.3.2.1. Comparison Analysis and Project Sizing

This subchapter will discuss methods from various articles for comparing project complexity. Comparative Analysis comprising a comparison matrix and a method for project sizing using the element of Complexity.

The comparison matrix is a methodology introduced by Hertogh and Westerveld (2009) where project complexity can be measured by dividing the project into detailed complexity and dynamic complexity. This concept is commonly applied in a large-scale infrastructure project in order to connect the management and complexity on those projects.

Detail complexity represents a large number of components and their connections, while dynamic complexity represents the possibility of development or limited understanding (Dunovic et al., 2014). These types of complexity are then tested based on several elements, which are technical, social, financial, legal, organizational, and temporal (figure 11).

Complexity	Detailed complexity	Dynamic complexity
Technical:	Large-scale product (scope) Many connections among parts of the product	Untried technology Technical uncertainty
Social:	Large number of interested parties Many connections	Conflict of interest Various meanings and perceptions Major impact on the environment
Financial	Costs and benefits are difficult to calculate and are not equally divided Perception of the development of costs which differs from calculations	Variable market conditions Different perceptions of definitions and agreements Strategic misinterpretation, optimistic / pessimistic bias 'Cascade of distortion' effect
Legal	Large number of approvals and permits Comprehensive legislation and policies have a significant impact on the content and process	Changeable, non-existent, and conflicting laws People need space for execution of activities (look for holes as extra space)
Organisational	Large number of organisations involved Large number of processes that interfere Large number of contracts	Find and keep motivated people adequate to the challenge. Large number of decisions with uncertain best solution Future development impacts the organization that delivers the project
Temporal	Planning of activities and their relationships	Long time frame with continuous development No sequential (step by step) implementation process, processes are carried out in parallel Planning contains a large number of uncertain and unclear processes

Figure 11 Detailed vs Dynamic Complexity Model
Source: (Hertogh & Westerveld, 2010)

Besides the previously mentioned measurement process, project complexity can also be utilized by dividing it into several levels, which is one effort of doing project sizing. Andrews (2015), in his research, makes some levelling of classification on project complexity through spreading questions to some experts and practitioners. Andrews divided projects into small complexity levels, medium complexity levels, and large complexity levels.

A scoring system is used to determine the category of project using several criteria such as life-cycle size and duration, project organization, technology, risk, visibility, and authorization. This methodology proved to create a more prepared management when setting their efforts towards the project's complexity.

Another methodology to classify project based on a certain level was done by Hass (2008) who proposed a comprehensive framework for assessing the scale of projects, which is categorized into three levels: independent, moderately complex, and highly complex. The framework utilizes a set of determining variables in the form of various questions. These questions pertain to factors such as time and cost considerations, team size, team composition and performance, urgency and flexibility in terms of cost, time, and scope, clarity of the problem, opportunity, and solution, volatility and risk requirements, strategic importance, political implications, multiple levels of organizational change, level of commercial change, risks, dependencies, and external constraints, as well as the level of IT complexity.

A similar method was also used by Brink (2016) to scale projects based on their complexity. Criteria used by Brink to scale the project are level of effort, team experience, financial resources, number of team members, number or size of deliverables, timeframe, cost, and change. This methodology is also mentioned in PMBOK, fifth edition, that one way to treat projects is by classifying them into several levels. A smaller-scope project tends to have fewer project responsibilities compared to a more complex project (Project Management Institute, 2013).

Implementing this levelling method in project classification can be one way to establish a standard for analysing the difficulty level of projects. The output is the formation of a standard to address or monitor the project based on its complexity level. This means that if a project with a similar complexity level is identified, the management already has a repository containing project monitoring tools to handle such types of projects (Brink, 2016).

2.3.2.2 TOE Concept

Another way to define project complexity is by classifying the cause into several themes and areas of complexity. The Technical, Organizational, and External (TOE) framework was formed to improve understanding and define project complexity (Bosch-Rekveldt et al., 2011). The framework was made by collecting several potential elements from several journals and interviews with practitioners, resulting in a framework that consists of 47 elements that can cause project complexity. These elements were then gathered into three main categories, which are the T, O, and E dimensions.

The T, O, and E obtained by defining the importance of a project cover aspects of technical and social purposes. The T, O, and E concepts represent the concepts of system and actor perspective, which also represent the concept of a project (Bruijn & Herder, 2009). The technical factor represents the traditional factor of the project, which becomes the point of view of the project manager and engineers; the softer aspect and human side are covered by the organizational aspect; and the external aspect, such as environmental and political aspects.

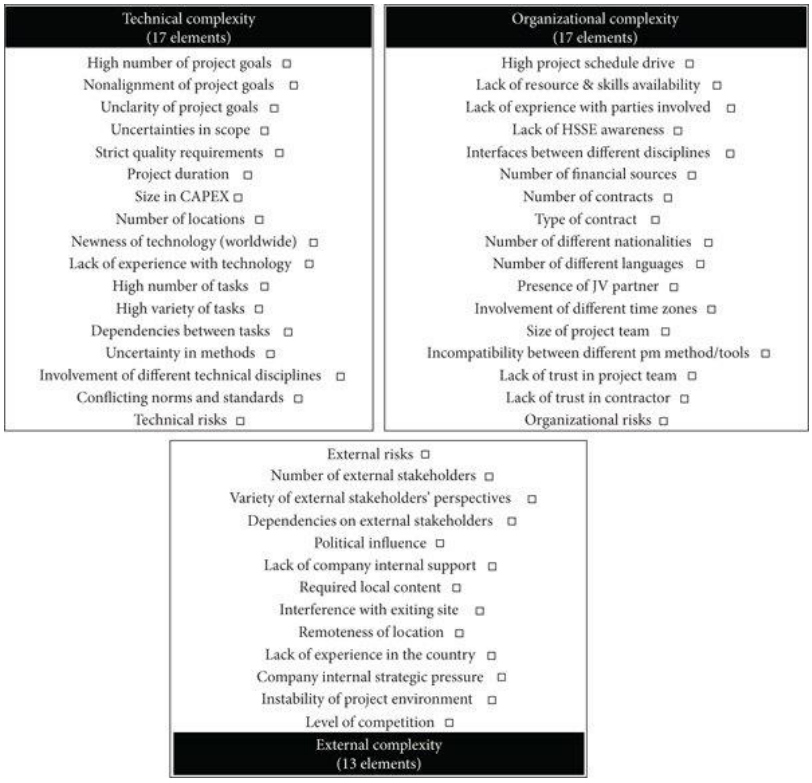


Figure 12 TOE Concept for Project Complexity
Source: (Bosch-Rekveldt et al., 2011)

The elements of TOE are also categorized based on the subcategories in each dimension. The technical aspect is divided into goals, scope, tasks, experience, and risk; the organizational aspect is divided into size, resources, project team, trust, and risk; and the environment, or external dimension, is divided into stakeholders, location, market conditions, and risk.

The application of the TOE complexity framework can help the project team to make a footprint of the project and also the expected events that might occur during the project. Geraldi (2009) on his research mentioning that project categorization can help to uncover significant challenges to the project, which this TOE serves a similar function. The concept of TOE can also be combined with the dynamic and detailed complexity described by Hertogh & Westerveld (2010). Mapping the TOE concept towards the dynamic or detailed complexity or project sizes can be done by the management as a way to define the project complexity they might face; for example, the number of stakeholders

involved in a project can sometimes be placed as a detailed complexity, or in other projects, it can be a dynamic problem.

More focused on the TOE complexity framework, Bosch-Rekveldt et al. (2018) also conducted another study to see how impactful the TOE complexity framework is on project complexity in the actual infrastructure project. The biggest 3 to 5 contributing elements on each dimension are shown in Table 5.

Table 5 Most Contributing Complexity Elements in Infrastructure Industry
Source: (Bosch-Rekveldt, Bakker, & Hertogh, 2018)

Most contributing to project complexity	Percentage of respondents
Technical	(N = 144)
Dependencies between tasks	38%
Uncertainties in scope	28%
Project duration	26%
Involvement of different technical disciplines	23%
Organizational	(N = 146)
High project schedule drive	36%
Interfaces between different disciplines	28%
Lack of resource and skills availability	23%
Building logistics and accessibility	22%
External	(N = 146)
Remoteness of location	50%
Variety of external stakeholders' perspectives	36%
Political influence	23%
Interference with existing site/projects	23%
Number of external stakeholders	21%

In the technical aspect, dependencies between tasks is the most frequent contributing complexity element that should be managed. In the organizational aspect, the high project schedule drive becomes the highest source of project complexity, while in the external part, the remoteness of location is the most impactful factor.

Regarding Earned Value Management, several elements within the TOE complexity framework have relationships that can influence and be influenced by Earned Value Management. By understanding the definitions of each element within the TOE complexity framework and the definitions of activities in Earned Value Management based on the ANSI/EIA-748 standard, there are 29 elements that are interconnected. These relationships can be observed in the table 6.

Table 6 Connection Between TOE Elements and EVM

TOE Aspect	**ANSI/EIA-748 Standard EVM Aspect**	**ANSI/EIA-748 EVM Scaled Aspect List**
High number of project goals	Project measurement baseline plan	Establish and maintain a time-phased budget baseline
Non−alignment of project goals	Project measurement baseline plan	Work authorization documents, Early PMB establishment; Control account plans
Unclarity of project goals	Project measurement baseline plan	Time-phased performance measurement baseline; Formal plan for each control account manager accomplish the authorized work within the time
Instability of project environment	Identification of unit cost	Identify unit cost, equivalent unit cost, or lot costs by type and amount of material
Company internal strategic pressure	Budget authorization; Management reporting	Internal reports (show budgets for each control account)
Size of project team	OBS	Organization Breakdown Structure intersections with WBS
High project schedule drive	Scheduling work; Calculate schedule variance	Distinct task using WBS to track progress, schedule variance
Lack of Resource & Skills availability	Budget by cost elements; OBS	Resource Plan

TOE Aspect	ANSI/EIA-748 Standard EVM Aspect	ANSI/EIA-748 EVM Scaled Aspect List
Lack of Experience with parties involved	Unauthorized revisions; Target cost goal;	Management performance reports
Interfaces between different disciplines	Discrete work and objective measures	Control account/work package plans
Number of financial sources	Accounting system and actual cost (scalability)	Actual costs report; Subcontract reported actual costs to payments; Internal and external performance reports for suppliers
Number of contracts	Unit and lot costs; Track and report; Incorporate changes	Price change mechanism; Change mechanism
Type of contract	Incorporate changes in a timely manner	Change mechanism
Technical risks	Undistributed budget; Corrective action; Maintain estimate at completion	Planning for overhead budget and risk budget; Taking corrective action (duration); Updating estimate
Organizational risks	Undistributed budget; Corrective action; Maintain estimate at completion	Planning for overhead budget and risk budget; Updating estimate
External risks	Undistributed budget; Maintain estimate at completion	Planning for overhead budget and risk budget; Updating estimate
Uncertainties in scope	Project Scope (WBS)	Detailing WBS
Strict quality requirements	Corrective action	Objective completion criteria; Corrective action
Project duration	Schedule; Maintain baseline and forecast schedule	Schedule planning; Maintaining schedule and forecasting schedule update
Size in CAPEX	Planned budget; Performance measurement baseline; Budget identification	Budget planning; Aspect in budget identification
Incompatibility between different pm methods / tools	Track and report; Allocation of indirect cost	Management performance reports; Cost collection structure
Dependencies on external stakeholders	Accounting consideration; Summarize performance data and variances for management reporting; Incorporate changes in a timely manner	Recording of direct and indirect cost; Report information and detail
Number of external stakeholders	Accounting consideration; Summarize performance data and variances for management reporting; Incorporate changes in a timely manner	Recording direct and indirect cost; Report change; Number of reports
High number of tasks	WBS; scheduling; identify products and milestone	Detail of WBS
High variety of tasks	WBS; scheduling; determine discrete work and objective measures; level of effort planning and control	Detail of WBS; Work package plans; Responsibility assignment matrix; Resource plan; Internal reports; The amount of LOE
Dependencies between tasks	WBS; schedule	Detail of WBS; Creating detailed objective on schedule and milestones
Uncertainty in methods	Track and report material cost and quantities	Reporting results and trends
Involvement of different technical disciplines	Structuring schedules for progress status and forecast; Resource budget for future effort	Budget resource; Authorization work into organizational element
Conflicting norms and standards	Record allocation direct cost	Accounting Standards

From all aspects of scalability and the standard procedures of Earned Value Management based on the ANSI/EIA-748 standard, Aramali et al. (2021) stated in their research that there are several elements that have a higher impact compared to other EVM elements. As mentioned in Figure 13, some aspects have high scores, wherein these aspects are part of Earned Value Analysis.

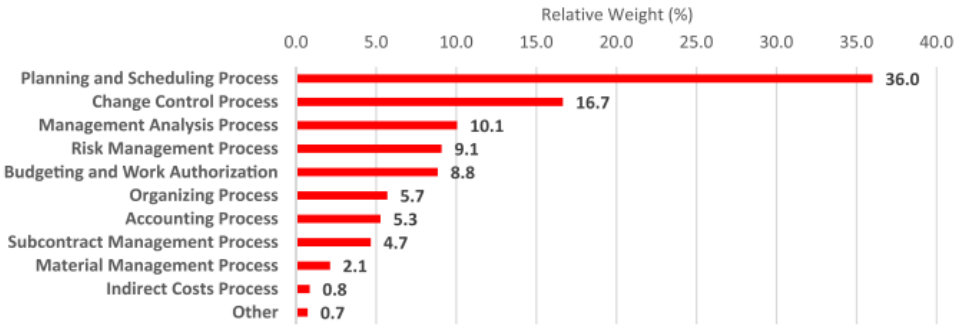


Figure 13 Impact Score of Earned Value Management
Source: Aramali et al., 2021

The Planning and Scheduling Process holds the highest position, and several aspects that are fairly high are Changes, Analysis, and Budget Authorization. Within the Planning and Scheduling, there are aspects related to Work Scheduling, Performance Measurement Baseline, and Budget Authorization (Figure 9). Therefore, to develop Earned Value Management and streamline the effort invested, priority can be given to these aspects with higher change impact, as several crucial points are already covered within the Earned Value Analysis aspect.

2.4. Conclusion

This chapter explains the theoretical background of this study which useful to answer the research question. The explanation phase of the literature review begins with the subchapter 2.1 discussion of the definition and explanation of project control and monitoring in general. Next is subchapter 2.2, which discusses the concept of Earned Value Management and the factors that influence its application. In this subchapter, the definition of Earned Value Management, its application and calculation methods are discussed, followed by an explanation of Earned Value Management's maturity level, which is related to the second sub-research question of this study, and an explanation of the 10-step model as the basis for the development of Earned Value Management in this study, which combined with the concept of Earned Value Management provided at subchapter 2.2.2. In addition, it discusses ANSI/EIA-748, which is a reference standard for enhancing Earned Value Management, and concludes with an example of an Earned Value Management development method that includes information about the scalability factor for EVM as suggested by NDIA towards the concept of 10-step model.

Chapter 2.2.6 delves into the intriguing possibilities for the advancement of Earned Value Management. The chapter discusses the practical development of frameworks, utilizing the 10-step model as the foundational basis, coupled with the potential for scaling using the scaling product recommendations outlined in the ANSI/EIA-748 Standard (Appendix C). However, it is important to note that while the scalability guideline from the ANSI/EIA-748 standard, mentioned in Appendix C, serves as a valuable reference to determine the potential aspects for EVM scaling, it lacks the depth to dictate the extent and methodology of this scaling where will be completed by the empirical study of this research. This concept can be applied in organizations that employ project sizing methods to analyse the complexity of their projects, where as an illustration, Van Oord employs the ABCD project classification concept. In the framework implementation, the scaling will be prioritized into the Earned Value Analysis as the most significant and impactful elements, then will be followed by the completing Earned Value Management System with the rest of the 10 step model (Project Goals, RAM, Results and Deliveries, and Analysis on Changes).

The final subchapter discusses the definition of Project Complexity, which includes a method for project identification and an analysis of TOE complexity, one of the variable aspects of this research. In relation to the TOE, the connection with EVM involves analysing which elements are linked to Earned Value Management and determining activity solutions within EVM implementation that can be undertaken to address these complex elements.

Conclusively, this chapter has yielded two distinct approaches for shaping the EVM framework, as evidenced in Table 4 for the ABCD EVM Framework and Table 6 for the TOE EVM Framework. Furthermore, an exposition on the theory concerning EVM maturity levels has been provided. While these concepts lay a crucial foundation and offer valuable insights to address the research questions, certain aspects remain outstanding. Specifically, the detailed components of activities within each framework, along with the connection between maturity and complexity levels within the EVM framework, which stands as subjects for further investigation in the subsequent empirical study.

3. Research Methodology

As concluded in the previous chapter, foundational frameworks are developed based on the integrated EVM 10-step model and TOE complexity. This section will delve into the methodology used for crafting these frameworks to address the sub-question number 3, including the methodology to ascertain the EVM maturity level to answer sub-question 2. This chapter will also consist of the reasons of choosing the methodology and how data to support this research is collected and analysed in order to provide answers to the research questions.

3.1. Research Methods and Flow

In accordance with the previously stated research question, "How to adapt Earned Value Management to various levels of projects based on the project complexity?", exploratory research has been selected as the method of research. Exploratory research is a technique used to discover new and intriguing insights into a topic of study. It consists of two categories: conducting an initial analysis of a new topic and developing new hypotheses based on existing topics (Swedberg, 2020).

This exploratory research will be highly valuable in determining how Earned Value Management can be effectively applied based on expert judgments. As the data collected is qualitative in nature, the data collection method involves conducting in-depth, semi-structured interviews with internal experts from the company under investigation, which are then compared with existing theory.

In general, this research will be conducted in several phases, during which data will be collected through literature reviews and interviews. This method's output will provide answers to the questions posed in Chapter 1. This research will begin by identifying problems based on the gaps identified in Chapter 1. The issue identified is whether Earned Value Management can adapt and transform in response to changes in projects. There has been no research to date that discusses the possible scale and range of developing Earned Value Management in detail and the factors that must be considered in relation to different project levels.

The next step is understanding theory that will be used as the basis for interview questions such as the significant element of Earned Value Management, maturity level of EVM, and potential scaling development aspects following the standard of Earned Value Management application issued by NDIA using ANSI/EIA-748 standards (answering sub-question 1). After that, interview questions formed to create the framework. The interview questions will be including elements of Earned Value Management which presented in the form of 10-step model and questions about project complexity. The steps are shown at figure 14.

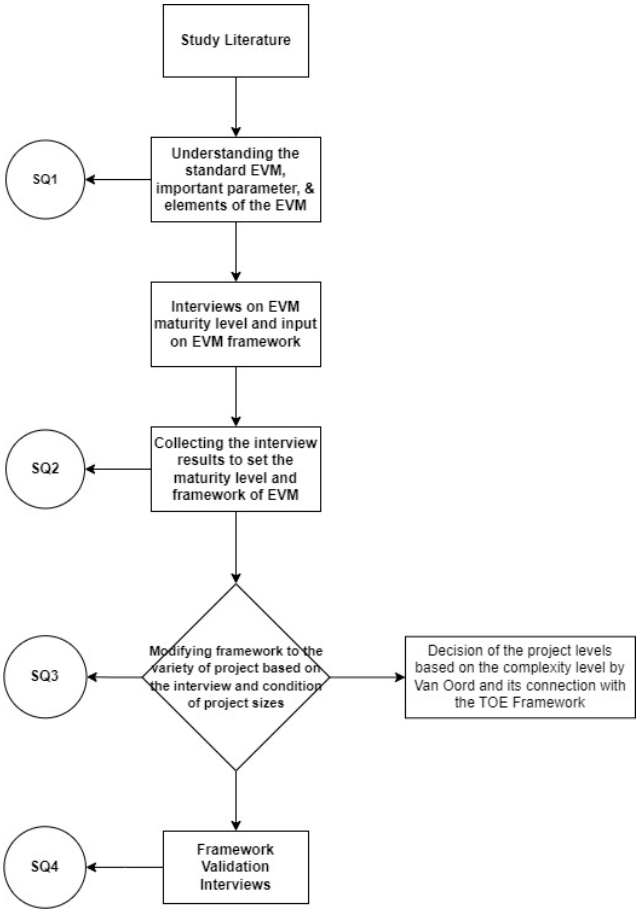


Figure 14 Research Methodology

The results of the interviews then will be analysed to determine the level of EVM maturity level and how EVM can be scaled to become a monitoring tool for projects of varying degrees of complexity. Analysis about respondent's understanding of Earned Value Management will answer questions about maturity levels (answering sub-question 2). During the interview, respondents will also be asked about the complexity of the project by distributing the questionnaires regarding project classification, and the TOE complexity framework utilized to classify projects. The process then continued by categorizing projects according to their respective levels of complexity following the ABCD project classification and projects which have high score in the 29 TOE elements mentioned in Table 6. Examining the frequent responses, suggestions from experts, answer on the follow-up question regarding the effectivity, and associated standards from the literature review is the method used to decide the suggested activities on the framework (answering sub-question 3). The final phase is conducting validation to gather suggestions from experts related the effort need to be done in order to improve the effectivity of the framework (answering sub-question 4).

3.2. Data Collection and Analysis

As mentioned in the previous section, in-depth interviews with Van Oord experts who have managed multiple types of projects with varying degrees of complexity are used for gathering data. In this section, the interview technique, the scope of the questions asked, the sample and population, data collection, and data analysis will be discussed. In the final section, the validation of this study's findings will also be discussed.

3.2.1. Semi-Structured Interview

The method used to obtain the main data in this study is through interviews with several experts who have experience handling projects with different scopes. The semi-structured interview was chosen because of the exploratory research method that this research wanted to conduct so as to allow the interviewee to provide more extensive information and produce more diverse results.

After determining that semi-structured interviews will be used to conduct this interview, the process will follow the research flow diagram shown below.

Figure 15 Interview Process

1. Preparing Interview Protocol and Informed Consent Form
   The initial step is to create an interview protocol containing the interview questions and procedure in conducting the interview. The interview questions corresponded to the sub-questions raised in this research to create the EVM framework.
   The things discussed are EVM maturity level, project complexity, and the basic concept of project monitoring, which are the variable aspects of Earned Value Management. Questions regarding the EVM maturity level seek to determine how far EVM has developed at Van Oord. The project complexity questions focus on the interviewee's understanding of project complexity and to identify the complexity of their own project. Questions regarding project monitoring were related to EVM component variables in the 10-step EVM model (Antvik & Sjoholm, 2012). Beside all relevant questions, respondents also being asked about their thought about their methodology whether it was suitable to create an effective result, or if they have suggestions on how to improve it further.
   Before the closing remarks, the interviewee will be asked for feedback on the interview that was conducted. This is done to get an impression from the interviewee of the interview process that was conducted as well as to get feedback on the questions asked so that the questions can be modified for future interviews. The interview protocol used in this study is detailed in Appendix A.
   Apart from preparing the interview protocol, an informed consent form was also prepared as a form of agreement that the interviewee is willing to participate in the interview process voluntarily. The informed consent form uses the research format issued by TU Delft, which can be done after completing the Human Resource Ethics Committee (HREC) form and Data Management Plan (DMP) form. This informed consent form will be sent to the interviewee prior to the interview so that the interviewee is aware of the potential risks associated with the interview process, and the interview will only be conducted if the interviewee agrees to the informed consent form provided.

2. Selecting Interviewees
   The next stage is selecting interviewees, setting interview criteria, and arranging a schedule for conducting the interview. The selection criteria sought were practitioners and staff from Van Oord who had experience with project monitoring or Earned Value Management. Proposals are submitted to several project managers, project controllers, or cost controllers from different levels. In addition, the experts chosen are who have been involved in working

on small to large-scale projects to find out the differences in the use of monitoring tools in those projects. In selecting candidates, the determination of respondents will go through approval from the company supervisor of this research so that the interviews conducted are more targeted and relevant. After that, the potential respondents are then approached via email with a brief introduction about the researcher and the topic that will be discussed, including his or her willingness to be involved in the research and location, as well as a place to do the interview.

The respondents of this research consisted of several practitioners with different positions, however all positions have relation to project execution. The respondents of this research as seen in table 7 will then be given a code to make this analysis more efficient and anonymous.

Table 7 Research Respondent

No	Job Title	Respondent Code
1	Project Controller	C1
2	Project Controller	C2
3	Business Controller	C3
4	Project Director	D1
5	Project Manager	M1
6	Tender Manager	M2
7	Engineering Manager	M3
8	Project Manager	M4
9	Lead Project Planning and Risk	P1
10	Project Planner	P2
11	Planning and Control Engineer Specialist	S1
12	Engineering Specialist	S2

3. Conducting the Interview

   The interview took place at the Van Oord office at a time mutually agreed upon by both parties. The option of using Ms. Teams as an online meeting platform also can be one of the methods of performing the interview if the condition to have an offline meeting is sufficient (i.e. the location of the respondents are outside Netherlands). Previously, the interviewee would receive a file containing an outline of the questions that would be asked as well as an informed consent form so that they could prepare any materials necessary to answer questions during the interview.

   Before starting the interview, the interviewer will ask the interviewee if they are willing to participate and remind them of the informed consent form. The interviewer will also request permission to record the meeting as documentation of the conducted interview, which recording process is also mentioned in the informed consent form. The results of this recording will be stored on the company drive of the interviewer.

4. Transcribing the Interview

   The results of the recorded interview will then be transcribed into text and used as primary data for the analysis of the findings. The transcription process will be assisted by Microsoft Word's transcription tool, and the interviewer will re-listen to the results to correct any words that do not correspond to what the speaker actually said. A number of modifications were also made to the recurrence of words unrelated to the research.

5. Interview Results Validation
   In the last phase of the interview process, validation of the interview results is sought from the interviewees. This validation occurs concurrently with the distribution of meeting minutes to the interviewees, along with an inquiry about any additional information that may not have been communicated during the interview. The purpose of this validation is also to demonstrate the transparency of the collected data and ensure that the information that will be used to create the frameworks are true.

3.2.2. Data Analysis

This chapter describes the methods and steps used to process the data obtained to answer the research questions posed in chapter 1. The data obtained from the interview are processed using the Thematic and Narrative Analysis to form the EVM frameworks.

3.2.2.1. Thematic and Narrative Analysis

The purpose of thematic analysis is to describe and organize data sets. This serves to classify the collected data into distinct themes for identification and analysis (Braun & Clarke, 2006). Using Atlas.ti software, a thematic analysis could be conducted to determine the frequency of data mentions and identify patterns of efficient data utilization. The results of the obtained and categorized data based on the theme will then be analysed and incorporated into the Earned Value Management framework as a category of variables.

According to Braun & Clarke (2006), choosing the appropriate approach must come before beginning the thematic analysis process. Regarding the data being analysed, Braun & Clarke (2006) state that a descriptive approach can be used to provide details on the theme of the data or investigate one aspect in detail. In this study, a descriptive approach will be used because thematic analysis is useful for obtaining primary data for further analysis.

Braun & Clarke (2006) also mention that thematic analysis can be approached inductively or deductively. Inductive coding is a bottom-up approach where the analysis is conducted based on the data set obtained and not on pre-prepared coding. While deductive is a top-down approach where the theme of the data is determined from a literature review. In this study, the hybrid combination of both deductive and inductive analysis will be used. The theme of making a framework uses a 10-step model (Antvik & Sjoholm, 2012) as the basis for the development of Earned Value Management with the focus on several potential scalability aspects of Earned Value Management as the approach of a deductive approach, and inductive approach to generate some important aspects which not covered on the predetermined set of code to enhance the findings.

The last approach described by Braun and Clarke (2006) is semantic or latent data management. Semantic is the use of explicit or exact data according to what the interviewee conveys, whereas latent is the interpretation of what the interviewee conveys. In this study, the interviewees' responses were directly incorporated into an analysis of the Earned Value Management framework assessment to be conducted.

The process proceeds as follows: once the recorded interviews have been transcribed into a text file, the subsequent step involves categorizing the data based on themes and specific questions, focusing on elements such as maturity level, complexity, and elements of Earned Value Management (Appendix E for ABCD EVM Framework and Appendix F for TOE EVM Framework). The next step is the grouping of effectiveness analysis based on the interview results to decide the Earned Value Management constituent activities on each of project levels.

The activity analysis for each element in the framework is determined using a narrative analysis approach. According to Oliver (1998), narrative analysis involves examining a collection of stories derived from multiple data sources to gain understanding of how individuals interpret their experiences. In addition, narrative analysis serves as a valuable tool for the examination and

interpretation of textual or visual data derived from diverse information sources, including interviews (Munisov, 2023). The employed methodology involves the examination of respondents' answers pertaining to these elements in order to conduct a narrative analysis. The collected responses consist of answers provided by participants, which are deemed effective or recommended for further development as an evaluation of the project they have been participated in.

3.2.2.2. Complexity Analysis

After the data is transcribed and categorized based on the theme, the project cases given by the interviewees were classified according to their level of complexity.

In order to group project complexity levels, this study will use the Van Oord approach mechanism, known as the ABCD project classification system and TOE complexity analysis as the completing tools. Moreover, with the condition that every project is unique, there might be some complexity parts on the project that have not covered by the ABCD project classification, therefore the TOE complexity will be useful to cover those complexity elements.

However, the ABCD project classification mechanism basically categorizes groups based on their risk levels, where level A categories for a very risky projects and level D categories for the less risky project. The evaluation was conducted using several questions posed by Van Oord, which included project-specific information (Appendix D). The questions that are included in a questionnaire include project financial data, contracts used, supply chain mechanisms, experience working on similar projects, project conditions and locations, relationships with clients, possible risks, and possible recovery if there is a change to the scope or contract. This questionnaire will then be completed by the respondents or project experts, and an evaluation mechanism will be implemented. Each of the answers will have their own weight and score which the total combined value determines which category the project will fall into based on its classification threshold (Table 8).

Table 8 ABCD Project Classification Threshold

Project Level	Min score	Max score
A	1250	2500
B	1000	1250
C	700	1000
D	0	700

Depending on the level of impact on the project, each question has its own percentage weight. In addition to the question, each answer to the question also has a score, which is multiplied by the question's point weight and added to the project's final score (Appendix D). The weight of this score is also derived from the analysis and calculation process of numerous experienced projects, as well as validation from several senior project management levels; therefore, it is rather difficult and impossible to add other questions in a short period of time, as this system has already been implemented by the majority of the organization, and it is necessary to reconsider the weights of points, scores, and threshold project scores so that the adaptation of new questions is possible.

Considering the ABCD project classification is a tool based on project risk, the next step is test the classification whether the ABCD project classification can be categorized as a method to classify projects based on complexity represented by TOE complexity analysis as the comparing variable by using multiple correlation analysis using SPSS. Multiple correlation analysis examines the association between a dependent variable and the combined influence of independent variables (Kafle, 2019). The correlaction will be seen from the value of “Sig. F change” with the threshold less than 0.05 to indicate correlation between both variable tested. Additionally, the “R square” will also indicate correlation status if the resulted scoe is above 0.5 (Arkkelin, 2014).

Beside the ABCD project classification, project assessment will also follow the TOE complexity analysis. Each project will be assessed using the 47 complexity elements to see which aspects are critical based on the perspective of the respondents. All the respondents were asked to fill the TOE with the details of each aspect related to their project on a scale from 1 (none) to 5 (very much), and the result is the identification of the complexity of the project from the point of view of Technical, Organizational, and External aspects. Therefore, if an element has a value of 0 or "Not applicable" - 1, it has little impact on the project; if it has a value between 2 and 3, it has a medium impact; and if it has a value between 4 and 5, it has a significant impact on the project.

Ideally, using the classification system from Van Oord is preferable because of several reasons. First is because project complexity has many aspects and elements (Baccarini, 1996). In addition, since this research project was conducted in Van Oord, it would make more sense if its classification adhered to the Van Oord assessment criteria. Moreover, Van Oord's level complexity classification includes the majority of construction industry project complexity definitions. Several attributes related to tasks, scope uncertainties, involvement of technical disciplines, interfaces, resource and skills availability, logistics and accessibilities, location, external stakeholders, and political conditions are the questions asked in the Van Oord's ABCD project classification questionnaire. However, some complexity elements which not covered in the ABCD questionnaire will be covered by the TOE complexity assessment.

3.2.2.3. EVM Maturity Level Analysis

The next analysis to be done is to determine the maturity level of Earned Value Management applied at the selected project. The method involves asking interviewees about their knowledge of Earned Value Management and how they apply it to the projects they are working on. The EVM maturity level theory developed by Stratton (2000) serves as the theoretical foundation for determining Earned Value Management maturity level.

Following the guideline mentioned in Table 1, the interview results will be then analysed to gather the application of mentioned determinant activities related to EVM maturity level to each of the project cases. The last step done is by doing validation about the current maturity level to gather feedbacks and suggestions.

3.2.2.4. Earned Value Management Framework Analysis

After the interview results have been transcribed and categorized based on themes and also the project cases have been categorized based on their level of complexity, the next step is to plan the EVM framework accordingly. There are 2 frameworks resulting in this research, the first one is the framework using the ABCD project classification as the main framework and the framework using the TOE complexity which focuses on certain elements related to Earned Value Management which having high score in terms of complexity as an improving framework. Both frameworks will be combined to cover some critical elements that are not covered by the ABCD project classification. The fundamental format for the ABCD EVM framework is the 10-step EVM model by Antvik and Sjoholm (2012), since this model covers most of the important aspect in the application of Earned Value Management, then this model will be modified and sorted to list the most significant aspect to the application of Earned Value Management, which prioritized from the Earned Value Analysis consist of the Planned Value, Actual Cost, and Earned Value. Some of the attributes from the 10-step model will be merged to the Planned Value which are WBS, Schedule, and Planned Budget following the findings from Lukas (2012) and NDIA (2018) standard, while for calculating variances and forecast will be involved in the Earned Value aspect. As shown in Appendix E, The scaling will follow the 10 core elements of Earned Value Management, while for the scaled factor will follow the scalability guideline from ANSI/EIA-748 standard (NDIA, 2020). The scalability guideline only serving as a literature to decide which aspect has the potential to be scaled in terms of using Earned Value Management, however to which extent these aspects can be scaled and how to scale these

aspects is not provided, therefore the interpretation from the interview process will answer the scaling threshold of each of this EVM elements.

Meanwhile the TOE EVM framework will not follow any set of Earned Value Management standard, instead the framework will become a set of suggested activities that can be done by the organization to cover the critical/high points resulted from TOE complexity analysis. The TOE elements first will be sorted into several aspect which have connection and correlation with Earned Value Management. The use of NDIA standard will become the main source of deciding which aspect of Earned Value Management has influence to each of the TOE elements. Suggested scaled aspect also be retrieved from NDIA guideline, while for the suggested activities will be obtained from the result of the interview.

The framework also will follow the rule of scaling-up framework which based on the report on Scaling Up and Scalability (Anandajayasekeram, 2016), scaling will start with what is implemented at project level D, and as the project level increases, some important aspect necessarily will also be applied on the higher level while adding some important aspect that were found in that project level following logical reasons for the implementation.

3.3. Results Validity and Reliability

This research is concluded by validating the applicability and relevance of the developed framework for project implementation. Validation will serve as an explanation of how accurate the collected data is and how findings can be generalized to other contexts, whereas reliability describes how researchers formulate the underlying formulas or construct frameworks (Sekaran and Bougie, 2016).

In this study, validity and reliability will be determined using an internal methodology in which data validation will be performed on interviewees and validation for framework will be determined through interviews with experts who were not involved in the data collection interview process. This validation procedure provides expert recommendations and opinions regarding the research methods and resulting framework. The validation procedure will cover the potential improvement of the resulted framework and the applicability at Van Oord. Validation was also performed to confirm Van Oord's Earned Value Management application maturity level.

4. Results

This chapter will describe the findings of this study. The first step is to describe the project cases that serve as the foundation for this research. The project cases were obtained through interviews with multiple respondents, and the resulting information were used to develop the EVM framework.

On the basis of the interview results, the organization's understanding of Earned Value Management, which will be defined by the EVM maturity level, is also assessed. The results of the interviews will be used to link organizational understanding to the EVM maturity level theory discussed in table 1.

The classification process at the project level will be discussed next to determine the extent to which the EVM can be scaled. As discussed in the preceding chapter, there are two classification methods for projects: the ABCD project classification method and the TOE project complexity analysis. In this chapter, there will be discussion about the identification of all project used for this research using both concepts. This chapter will also discuss, based on the results of the interviews, which elements will be included in the framework and methods for selecting activities that can be performed in relation to Earned Value Management at each project level.

4.1. Project Cases

The project cases utilized in this study represent a variety of projects conducted by respondents who were interviewed. The majority of projects discussed were Offshore Windmill and Dredging projects. In addition to these two projects, there are two additional projects for comparison and consideration: road and port construction.

Twelve respondents with diverse backgrounds, but still within the field of project execution (project manager or controller) were interviewed. During the interview, each respondent provided two sample projects for discussion and comparison. Twenty-two projects were discussed in total, but two projects were mentioned by two different individuals, so only data on twenty projects were gathered. Table 9 provides the detail of the cases used in this research.

Table 9 Respondent and Interview Lists

No	Job Title	Respondent Code	Project List			
			Project Type	Project Code	Project Type	Project Code
1	Project Controller	C1	Installation Project in China	I1	Dredging Project in Sweden	D6
2	Project Controller	C2	Installation Project in Northern Sea	I2	Installation Project in North Holland	I5
3	Business Controller	C3	Installation Project in South Holland	I3	Dredging Project in Angola	D7
4	Project Director	D1	Installation Project in China	I1	-	
5	Project Manager	M1	Dredging project in Poland	D1	Dredging Project in Georgia	D8
6	Tender Manager	M2	Dredging project in Qatar	D2	Dredging Project in Dubai	D9
7	Engineering Manager	M3	Installation Project in Mozambique	I4	Dredging project in Denmark	D10
8	Project Manager	M4	Installation Project in Mozambique	I4	Installation Project in Guyana	I6
9	Lead Project Planning and Risk	P1	Construction of highway in Netherlands	C1	Infrastructure Project in Netherland	D11
10	Project Planner	P2	Dredging Project in Dubai	D3	-	
11	Planning and Control Engineer Specialist	S1	Dredging Project in Australia	D4	Dredging Project in Middle East	D12
12	Engineering Specialist	S2	Dredging Project in Jordan	D5	Construction Project in Costa Rica	C2

The respondents are categorized based on their areas of expertise, including Controllers, Managers, Planners, and Specialists. The projects encompass Dredging, Installation, and Construction across diverse locations, with a significant number of these projects executed by Van Oord. To ensure both anonymity and analytical efficiency in evaluating the interview outcomes, each respondent is assigned a unique code.

4.2. EVM Maturity Level

For this study, the EVM maturity level will be assessed using the five-level framework popularized by Stratton (2006), which categorizes the EVM maturity level into five distinct levels. The responses from the participants varied significantly in their comprehension of Earned Value. Nevertheless, in general, Van Oord has incorporated several essential concepts from Earned Value Management, particularly in all the projects used as cases for this research. The results of the interviews, as indicated in table 10 and quotes mentioned, reveal that all the projects selected as the cases for this research have implemented the fundamental concept of Earned Value Management (EVM), which involves comparing planned progress with actual achievements.

Table 10 Application of Earned Value Concept on Project Cases

Earned Value Concept	Project Applying the Concept
Calculation of SPI and CPI	D11
Regular Variance Update	D11; D9; D2; I1; D7; I3; D3
Forecast Update	D11; D9; D2; D7; I3
Analysis on spending vs plan	D11; D9; D2; EA1; HKN; I1; D5; C2; D4; D12; D7; I3; D3; D1; D8; D6

"So we didn't measure earned value in that respect, OK, we we had to execute this channel. You know it should be this wide and this deep. So you have your survey data and based on that you update your progress to the client" – D6 (Respondent C1)

"you can translate that with the weekly cost to get an idea. Of earned value. However, it's not, yeah. It's not incorporated in the financial reporting" – D1 (Respondent M1)

"It depends a little bit on the the type of project that you run because we usually work with percentage of completion method…" – D7 (Respondent C3); (Respondent being asked about methodology in calculating Earned Value)

However, it was observed that only a few projects have applied advanced activities and calculations related to EVM, such as regular calculations on project variance and forecasts i.e. project D11; D9; D2; D7; I3, or the utilization of key metrics like Schedule Performance Index (SPI) and Cost Performance Index (CPI) for instance project D11.

According to Stratton (2006) on the distinction of EVM maturity level on Table 1 and based on the selected project, the organization is estimated to have a level 1 in the Earned Value Management maturity level. This level signifies that the company has limited application of Earned Value Management Concept and only done within a few projects, although the company has create an effort on starting to implementing the concept of Earned Value Management. Despite some of the selected projects already implementing a mature concept of Earned Value Management (D11 applying Schedule Performance Index and Cost Performance Index), based on Table 1, since it is not applied to all selected projects within the organization, so the maturity level is estimated to be at level 1. However, it is important to note that these findings could be subject to change pending validation on whether the organization consistently supports and facilitates the application of Earned Value Management across all projects as well with the similar details.

4.3. Project Classification

The project discussed in the interview underwent analysis using the ABCD levelling methodology and identified its characteristics through the TOE elements. The questionnaires were administered either during the interview or afterwards, if necessary. However, despite multiple follow-ups, two out of twelve respondents (M3 and M4) did not provide their assessments, resulting in incomplete data for projects I4, I6, and D10. As a consequence, these projects could not be compared with the others or categorized into levels. Thus, out of the total of 20 identified projects, 17 were used as the foundation for developing the framework in this research.

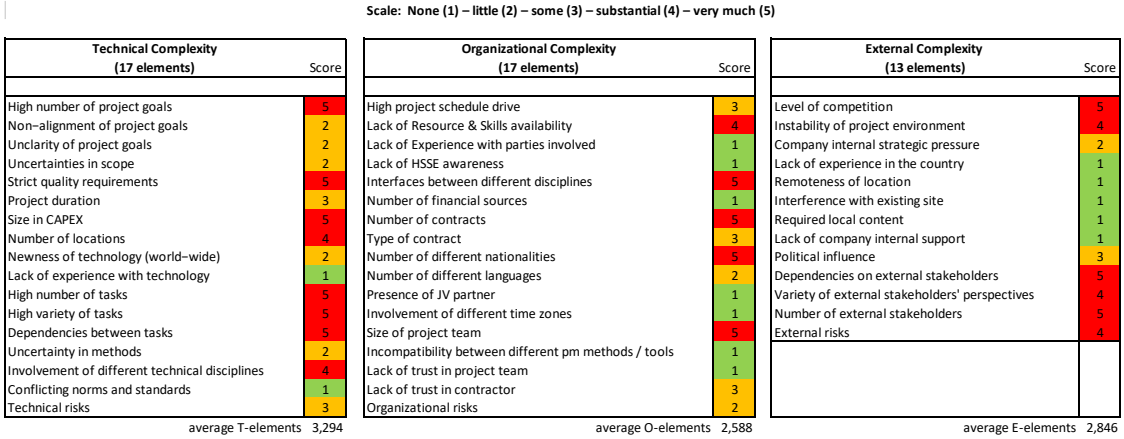
Out of these 17 projects, all of them were analysed for their project level based on ABCD and TOE complexity. Based on the results of the questionnaire filled by respondents, the distribution of projects based on the ABCD level can be seen in table 11 while for project scores based on the TOE aspect in Appendix G.

Classifying the project according to the ABCD Project Classification level is the initial step. When classifying a project, the respondents were given a questionnaire to complete. The questions in the questionnaire pertain to the potential risks associated with the upcoming projects. The determination of these questions are based on discussions with senior-level project managers, testing numerous of Van Oord-implemented project cases, and analysing which factors have a significant impact on the successful completion of the project.

Table 11 Project List based on ABCD Classification

ABCD Project Classification	List of Project
A	C1, D1, D9, D11
B	C2, D6, I3, I5
C	D2, D3, D4, D8, D12, I1, I2
D	D5, D7

In a comparable manner, for project classification using TOE, as described in Chapter 2, it is used to characterize and identify the project in order to determine which aspects are deemed crucial based on the value of each element. However, it is not recommended to use TOE as a single value for a project; rather, it is possible to combine scores based on Technical, Organizational, and External factors (Bosch-Rekveldt, 2010).



Scale: None (1) – little (2) – some (3) – substantial (4) – very much (5)

Technical Complexity (17 elements)	Score
High number of project goals	5
Non–alignment of project goals	2
Unclarity of project goals	2
Uncertainties in scope	2
Strict quality requirements	5
Project duration	3
Size in CAPEX	5
Number of locations	4
Newness of technology (world–wide)	2
Lack of experience with technology	1
High number of tasks	5
High variety of tasks	5
Dependencies between tasks	5
Uncertainty in methods	2
Involvement of different technical disciplines	4
Conflicting norms and standards	1
Technical risks	3
average T-elements	3,294

Organizational Complexity (17 elements)	Score
High project schedule drive	3
Lack of Resource & Skills availability	4
Lack of Experience with parties involved	1
Lack of HSSE awareness	1
Interfaces between different disciplines	5
Number of financial sources	1
Number of contracts	5
Type of contract	3
Number of different nationalities	5
Number of different languages	2
Presence of JV partner	1
Involvement of different time zones	1
Size of project team	5
Incompatibility between different pm methods / tools	1
Lack of trust in project team	1
Lack of trust in contractor	3
Organizational risks	2
average O-elements	2,588

External Complexity (13 elements)	Score
Level of competition	5
Instability of project environment	4
Company internal strategic pressure	2
Lack of experience in the country	1
Remoteness of location	1
Interference with existing site	1
Required local content	1
Lack of company internal support	1
Political influence	3
Dependencies on external stakeholders	5
Variety of external stakeholders' perspectives	4
Number of external stakeholders	5
External risks	4
average E-elements	2,846

Figure 16 Filling Example of TOE Complexity

Based on this evaluation, a weighted average assessment is performed for each aspect of each project. As shown in Figure 16, the Technical project value for the example project is 3,294, while the

Organizational project value is 2,588 and the External project value is 2,848. This is done for all project cases whose evaluation results are displayed in a table 12, Several level A projects have average scores for the Technical, Organizational, and External aspects that are high, whereas level D projects have a tendency to have average scores for the Technical, Organizational, and External aspects that are low. In Table 13, the differences between the ABCD scores and the scores for each TOE element are also demonstrated. This indicates that the majority of level A projects have high scores for each complexity aspect, level B and C projects are at a medium level, while level D projects also have low scores for each complexity aspect.

Table 12 TOE Score for Project

Project Code	ABCD Category	T	O	E
C1	A	4,059	3,294	3,385
D1	A	3,647	3,294	3,000
D11	A	4,118	3,471	3,385
D9	A	2,765	2,765	1,308
I3	B	3,118	2,706	1,769
C2	B	2,824	3,059	2,615
D6	B	1,882	1,529	2,154
I5	B	3,249	2,588	2,846
D4	C	2,471	1,824	2,077
I2	C	2,647	2,588	2,538
D2	C	2,118	2,647	2,154
D12	C	3,353	3,000	2,769
D8	C	2,118	2,118	2,538
D3	C	2,765	3,059	2,538
I1	C	2,118	3,000	2,692
D5	D	1,412	1,882	1,846
D7	D	1,000	1,706	1,308

Table 13 Project Level Comparison to Each TOE Element

Project Name	ABCD Category	T	Project Name	ABCD Category	O
D11	A	4,118	D11	A	3,471
C1	A	4,059	C1	A	3,294
D1	A	3,647	D1	A	3,294
D12	C	3,353	C2	B	3,059
I5	B	3,249	D3	C	3,059
I3	B	3,118	D12	C	3,000
C2	B	2,824	I1	C	3,000
D9	A	2,765	D9	A	2,765
D3	C	2,765	I3	B	2,706
I2	C	2,647	D2	C	2,647
D4	C	2,471	I5	B	2,588
I1	C	2,118	I2	C	2,588
D2	C	2,118	D8	C	2,118
D8	C	2,118	D5	D	1,882
D6	B	1,882	D4	C	1,824
D5	D	1,412	D7	D	1,706
D7	D	1,000	D6	B	1,529

Project Name	ABCD Category	E
C1	A	3,385
D11	A	3,385
D1	A	3,000
I5	B	2,846
D12	C	2,769
I1	C	2,692
C2	B	2,615
I2	C	2,538
D8	C	2,538
D3	C	2,538
D6	B	2,154
D2	C	2,154
D4	C	2,077
D5	D	1,846
I3	B	1,769
D9	A	1,308
D7	D	1,308

The project's category will serve as the foundation for developing a framework with illustrative examples for the ABCD EVM framework level A, where in this regard, information from projects C1, D1, D11, and D9 will be taken into account. However, the utilization of the TOE value in this context is solely employed for project identification purposes, taking into account the complexity of the project. However, when constructing the framework, the complexity of each individual element will be later considered on the TOE EVM framework.

4.4. Project Classification Comparison and Correlation Test

Both of the classification methods can be visibly seen to have a correlation with their complexity levels. As seen in Table 13, projects classified as level A generally have high scores for each element T, O, and E. Similarly, for project level D, there are low TOE scores, while project levels B and C have TOE scores that are quite similar. For further validation, a multi-correlation analysis was conducted using SPSS to test whether the ABCD Project Classification is correlated with the complexity theory represented by the TOE Complexity framework.

As explained in subchapter 4.3, the complexity of projects shows variability. The definition of project complexity even varies among respondents, as indicated by the quotes resulted from the interviews.

"For the complexity, it's. It's various things. It can be the base of the product, that it's a high accelerated product where you don't have time to properly analyze and make proper assessments and take the right decisions could well be that it's complexity is. In the multiple partners or stakeholders you have that can be internal external stakeholders. Complex it can be also in the technical complexity. If you build something in the middle of enter them, it will be different than if it's just somewhere in the portal. So it's technical complexity, it's complexity on the market, it's complexity and it's stakeholders" – P1

"Thinking well, I thought it is the level of unpredictability when when you do things, a lot of uncertainties and predictability…" – D1

"The complexity can be in the amount of different activities which are related to each other. But also the complexity can be in the location. And how to get can be a very easy job. If it takes a month to get there, the complexity It's it's, it's not in the time. Is is not in activities, but the complexity is the remoteness. Yeah, there can be so many factors" – S2

Van Oord, as an organization, employs a distinct system for categorizing projects into various levels. The purpose of this tool is to streamline the evaluation procedure and facilitate the decision-making process for organizations in identifying suitable strategies for anticipating specific project types. Similar findings can be observed in various other cases, such as in the study conducted by Brink

(2016), wherein project sizing was undertaken by considering multiple variables, including the size of the project team, elapsed time, timeframe, complexity, strategic importance, political importance, total cost, level of change, dependencies and interrelated projects.

Van Oord's utilization of the ABCD questionnaire can be regarded as an activity to undertake project sizing. Regardless of whether the ABCD method is considered a component of complexity, it is imperative to examine its correlation with the TOE complexity theory employed in this research. The dependent variable in this study is the ABCD project classification score, while the independent variables include the Technical aspect scores, Organizational aspect scores, and External Aspect Scores.

The test was conducted utilizing the dataset presented in Table 12, which pertains to the comprehensive evaluation of project scores. Modifications were made to the ABCD scoring system, assigning a value of 4 to score A (indicating a significant score), 3 to score B, 2 to score C, and 1 to score D. The obtained results were derived from the statistical analysis conducted using SPSS.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.818[a]	.669	.593	.641	.669	8.756	3	13	.002

a. Predictors: (Constant), External, Organizational, Technical

Figure 17 Multiple Correlation Score Test

According to the findings of the SPSS analysis examining the connection between ABCD and TOE complexity, the Sig. F change value displays a score of 0.002. The established significance threshold for this analysis is set at <0.05, indicating that a correlation between the two variables is considered statistically significant, moreover also can be seen from the value of the R square with the threshold of the score should be 0.5 to be identifiably significant (Arkkelin, 2014) and based on the analysis resulting R square value of 0.669 which indicating correlation. According to the findings of the correlation analysis, there exists a statistically significant relationship between the ABCD project classification and the complexity of TOE. Based on the information provided, it can be inferred that the ABCD project classification is considered a component of the complexity classification methodology.

4.5. ABCD Earned Value Management Framework

Van Oord is a company that is trying to implement Earned Value Management in a number of its projects. Based on the results of the interviews, it was determined that a number of respondents were aware of the use of Earned Value Management in projects on which they had worked.

Furthermore, it is important to note that Van Oord has already developed its own project classification method. Therefore, it would be more feasible and pragmatic to align the project classification method used in the establishment of the Earned Value Management framework with Van Oord's existing classification method, specifically the ABCD project classification method.

The proposed framework will be developed by employing a 10-step model as proposed by Antvik (2013) with the suggested scaled elements retrieved from ANSI/EIA-748 guideline (NDIA, 2020) and other literature on what is the significant aspect of Earned Value Management (APM Knowledge, 2008; Reichel, 2006; Lukas 2012). The objective of this procedure is to ensure that the elements being scaled are more focused and specific to multiple aspects that, according to existing literature, possess the potential for scalability and a substantial impact on Earned Value Management.

These attributes then will be divided into several control variables with the reason that these variables have the potential to be developed (NDIA, 2020) and also some important findings from the

interviews. In deciding the composition of the framework, several methods are being used. The first method conducted to assess the interview result for the framework composition is by determine the frequency of the method's use in the project that serves as the case for the study, under the assumption that all projects that employ the method have not discovered any issues with its application. As part of the interview, they will be asked the follow-up questions whether the method is effective and whether they have any suggestions for enhancing the project monitoring activities. Therefore, the method that will become a part of the Earned Value Management framework is the recommended and most commonly suggested method. Appendix I showing the quotes retrieved from the results of the interviews as the consideration of applying the suggested activity on the framework.

In presenting the framework, this research will be elaborated through the critical element of Earned Value Analysis as the highlighted elements and the rest of the 10-step model as the supportive elements that can be considered by the company to implementing Earned Value Management following the concept of 10-step model (Humphreys, 2012; Antvik. 2013):

- Earned Value Analysis
    - Planned Value (Source of budget) → WBS, Schedule, Budget
    - Actual Cost (Recording and monitoring of actual cost)
    - Earned Value (How to measure earned value and how often does it has to be done)
    - Variances (Schedule variance and cost variance)
    - Schedule Performance Index and Cost Performance Index (CPI & SPI)
    - Forecast (Estimate at completion)
- Earned Value Management System (Supportive information for organization to perform Earned Value Management which are the rest step from the EVM 10 step model)

The deductive method will be conducted on this framework where the set of theme and code been determined before the interview results being analysed (Appendix E). The main themes are decided by following the 10-step model sorted with the concept of Earned Value Analysis, while the code following the suggested scaled element from ANSI/EIA-748 standard as shown in Appendix C. However, not all of the standard will be included, instead it will be adjusted to following the baseline of the 10-step model and some aspects are combined.

Subsequently, a framework outlining recommended Earned Value Management activities is presented in Table 14. This framework adheres to the adapted 10-step model and incorporates the scaled aspects detailed in Table 4. Notably, the highlighted EVA aspects underscore the significance of these procedures, signifying their role in the effective implementation of Earned Value Management.

Table 14 ABCD EVM Framework

EVM Element	Scalability Aspect Based on NDIA	Scaled Product	A	B	C	D
Planned Value	Authorization of Work Scope	WBS	WBS developed until the level of activity package	WBS developed until the level of planning package	WBS developed until the level of planning work package (1 level below control account)	WBS developed until the level of Control Account
	Schedule Scope	Integrated Schedule	Project schedule plan on each activity also integrated with plan from subcontractor and validation created by calculating on potential of unmeasured activity beside calculating production estimate	Assumption and judgement required to validate schedule plan; specified planner controlling schedule and critical cycle on site	Assumption and judgement required to validate schedule plan; analysing critical equipment cycle time controlled by project manager	Aspect of project schedule determined until created significant interdependencies between segments of work; Creating project schedule plan using estimation to each of the activity
		Integration of Schedule to WBS	Level of details and sequence on activity level	Level of details on the planning work package level	Level of details on the planning work package level	Level of details until the control account level (Level of project manager)
		Setting Project Milestone	Having shorter intermediate internal milestone (i.e. weekly control on milestone achievement)	Creating intermediate internal milestone (i.e. monthly control on milestone achievement)	Creating intermediate internal milestone (i.e. monthly control on milestone achievement)	Milestone following what set by contract
	Budget Scope	Planned Budget	Detail of planning budget summary until the level of activity package; Class 1 Estimate	Detail of planning budget until the level of planning work package; Class 2 Estimate	Detail of planning budget until the level of planning work package; Class 2 Estimate	Detail of planning budget summary enough until the level of Control Account; Class 3 Estimate
	Planning Budget for Future Effort and Unmeasured budget	Non-measurable and future effort budget	Creating probability calculation of each of detailed activity to define the possible risk which require extra project budget (budget fixed)	Creating measurement on currency and possible changing of rates (fixed budget)	Creating percentage on budget spare from planned budget; In terms of using extra budget, using the concept of balancing act if there are still some budget left	Creating percentage on budget spare from planned budget
	Indirect budget	Indirect Budget Plan	Calculating integrated calculation to include the percentage of indirect cost.	Indirect cost is percentage markup on each activity involving the use of indirect cost	Indirect cost becoming percentage of budget summary	Having fixed indirect rates cost
	Management Reserve and Undistributed Budget	Planned Budget	Having risk measurement and risk manager to review risk possibilities and update the risk change regularly	Having risk manager to handle on risk budget and measurement	Project manager responsible for risk change and risk budget	Management reserve and undistributed budget for risk measurement may not specified in this project level, instead included in the unmeasured budget calculation, however project manager keep informed about incident which require spending
Actual Cost	Cost incurred for executing work on a project	Reporting Actual Cost	Recording actual cost on activity level (Extensive and detailed report); Survey team	Recording actual cost on planning work package level; having survey team to monitor	Recording actual cost on planning work package level; having survey team to monitor	Recording actual cost on control account level (Summarize cost); May using

EVM Element	Scalability Aspect Based on NDIA	Scaled Product	A	B	C	D
			on monitoring project progress; Using integrated system	the progress of the project	the progress of the project	estimated actuals for analyzing and reporting current performance
	Accounting System for Materials (Including source, workers, consumption)	Actual Allocation of Material Used	Using a more extensive system of monitoring materials as well as monitoring update on change and procurement; monitoring to more all aspect of material value (impact of using extensive tools i.e. cleopatra)	Using a more extensive system of monitoring materials; focus on all aspect of material value	Using a more extensive system of monitoring materials; however focus can be limited to only critical important material	Cost control tools enough of using simple financial spreadsheet that is separate from the accounting system; In the report should be highlighted the critical important material
	Update on financial condition	Report on Finance	Weekly budget financial update	Monthly update on financial condition	Monthly update on financial condition	Quarter update on financial condition with business unit
Earned Value	Quantification of worth the work to date	Updating on project progress	Monitored in S-curve format also to set project traffic; Using Daily Progress Report to monitor change of milestone	Using Daily Progress Report also to comparing money spent vs planned as consideration of achievement	Using a more extensive Earned Value system such as implementing S-curve to compare actual vs plan	At minimum using percentage to measure Earned Value (comparing what being achieved to milestones set)
	Reporting Variance	Update on variance report	Variance calculated based on value (schedule and cost); focus on critical variance (SPI and CPI Movement); included on the monthly report	Variance calculated based on value (schedule and cost); focus on cumulative variance; included on the monthly report	Variance calculated based on value (schedule and cost); generating cumulative variance; included on the monthly report	Variance can be limited into percentage of differences (Schedule and Cost); Generating cumulative variance; Included on the monthly report
	Forecasts	Forecast and Estimate at Completion	Weekly update on cost update and estimate at completion to the level of activity level	Monthly update on forecast and estimate at completion to the level of planning work package	Monthly update on forecast and estimate at completion to the level of planning work package	Monthly update on forecast and estimate at completion to the level of control account
Project Goals	Having clear goal	Project Goals	Project Goals on all project levels are similar which cover clarity, aiming for project profit, finish within time and budget, and safe. There is no scaling aspect in terms of creating project goals.			
Organization Breakdown Structure	Team Member	Organization Composition	Subcontractor becoming part of the team which having aligned goal and way of working; team until the level of work package/activity level	Fairly extensive team member until the level of superintendent/work group package	Fairly extensive team member until the level of superintendent/work group package	Involvement of 5-6 people from main organization
	Structural OBS	OBS	Require clear structure of project team and OBS aligned with WBS	Having defined organization structure (OBS)	Having defined organization structure (OBS)	Not requiring structural OBS (limited to responsibility assignment matrix and control account)
Responsibility Assignment Matrix	Workflow of working	Communication chain	Following a mechanism of asking approval using formal documentation; approval comes from project manager	Project manager gathering all reports from team to deliver reports to business unit (involvement of higher manager level)	Simple report and discussion with project manager	Simple report to project manager
	Handling subcontractor	Responsibility on Subcontractor	Subcontractor involved on the construction team	Subcontractor report to package manager	Subcontractor report to package manager	No subcontractor involved; if there is subcontractor, minimal of one person handling on

EVM Element	Scalability Aspect Based on NDIA	Scaled Product	A	B	C	D
						subcontractor
	Handling corrective actions	Corrective Action	Having quality controller on activities involving risk analysis; project director involved in decision on corrective action	Risk manager involved to handle risk and updated condition; decision come from project manager	Package manager taking action in terms of indirect cost activity, project manager taking control if money involved	Project Manager taking action in terms of risk
Results/Deliveries	Change of Performance Measurement Baseline	Regulation on Changes	Implementation of change procedure and having variation register to record change regularly; updating trend weekly	Implementation of change procedure; updating trend weekly	Implementation of change procedure; updating trend weekly	Change comes from project manager; updating trend on weekly basis
	Preparing Summarized Information for Management Evaluation	Report Information	Reported information include every important updates, also information about market condition and change of price and method to be reported quarterly with management	Reported information upgraded with additional information related to environment condition and market update; extensive report delivered quarterly	Reported information upgraded with additional information related to environment condition and extensive report delivered quarterly	At minimum report about trends, safety, and lesson learned included in the report to be reported quarterly with management
	Reporting indirect cost	Report Information	Indirect Cost should be included in the Summarized Report for all project levels.			
	Reporting subcontractor activity	Report Information	Subcontractor activity report detailed until the activity level	Subcontractor activity summarized into planning work level	Subcontractor activity summarized into planning work level	Subcontractor activity summarized into control account level
Analysis	Baseline change request	Tools to support change	Formal workflow process, forms, and logs to document changes	Having dashboard on monitoring change on logs	Having dashboard on monitoring change on logs	Having simple activity log

4.6. TOE Earned Value Management Framework

Based on the analysis of TOE complexity, it is possible to formulate an Earned Value Management framework. Related to the impossibility to consolidate the TOE classification into a single project complexity score, therefore, the framework established through the TOE complexity analysis method will take the form of guidelines or recommendations for Earned Value Management-related activities, aimed at addressing each critical element of the TOE.

This framework is developed by examining the specific components of the TOE complexity assessment that influence Earned Value Management. This categorization is achieved through a comparison between the definitions of each element in the TOE complexity and the definitions provided by the ANSI/EIA-748 EVM standard (NDIA, 2018), as well as the scalability guidelines outlined in the ANSI/EIA-748 standard (NDIA, 2020) for Earned Value Management.

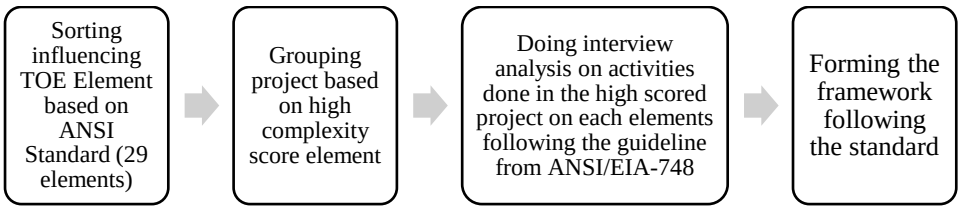


Figure 18 Procedure of Creating the TOE EVM framework

Among the 47 elements associated with TOE complexity, a subset of 29 elements has a direct influence on Earned Value Management. These elements encompass various factors, including objectives, market conditions, project team composition, resource allocation, risk evaluation, scope definition, project scale, stakeholder engagement, and task execution. Each of these 29 elements is linked to a specific aspect of Earned Value Management, aligning with the ANSI/EIA-748 standard. Furthermore, each element is equipped with a set of guidelines detailing the areas that can be adapted to effectively manage this complexity proactively.

The following phase involves categorizing projects based on the complexity of individual TOE elements. As previously mentioned, each project is distinctive, yielding varying element values. Alongside the restriction that TOE values cannot be aggregated, the projects are segregated into three complexity tiers (low, signifying a score of 0-1; medium, denoting a score of 2-3; and high, indicating a score of 4-5) for each element.

However, given that this framework is intended to complement the activities outlined in the ABCD EVM framework, the aspects under scrutiny and emphasis are exclusively the Earned Value activities recommended for high-complexity projects (score 4-5). The projects fitting this category are listed in Appendix H. The ensuing step entails scrutinizing the interview results, in line with the grouping process.

The formulation of the framework's structure will follow a method similar to that of the ABCD EVM framework. Meanwhile, for the implementation of Earned Value Management, each suggested activity, derived from ANSI/EIA-748 to address each element, will be evaluated and determined based on insights garnered from the interviews.

As demonstrated in Appendix F, the approach to these results unfolds sequentially. It commences with the corresponding TOE element and progresses into the overarching theme, determined through an analysis of the ANSI/EIA-748 standard to identify aspects connected to that specific element. Subsequently, a potential scaled list is developed, employing a methodology that selects products from the ANSI/EIA-748 aspect standard and scalability guide (see Appendix C) capable of addressing the complexity element effectively. Finally, the last step involves analysing the interview findings to identify the most impactful activities cited in the cases associated with each complexity element.

Nevertheless, given the absence of a standardized approach for applying Earned Value Management, the recommended activities encompass strategies to address each of the 29 elements. These activities shown in table 15 can serve as supplementary components to the ABCD EVM Framework. Appendix J presents quotes extracted from the interview findings, which serve as valuable insights for incorporating the suggested activities into the framework.

Table 15 TOE EVM Framework

TOE Aspect	Related EVM Aspect based on ANSI/EIA-748 Standard	ANSI/EIA-748 EVM Scaled Aspect List	Added EVM Activity for Each High Element Score
High number of project goals	Project measurement baseline plan	Establish and maintain a time-phased budget baseline	Having a detailed cost to schedule plan until the level of activity
Non−alignment of project goals	Project measurement baseline plan	Work authorization documents, Early PMB establishment; Control account plans	Creating work authorization plan until the level of activity, report to package manager
Unclarity of project goals	Project measurement baseline plan	Time-phased performance measurement baseline; Formal plan for each control account manager accomplish the authorized work within the time	Weekly update on goals and objective
Instability of project environment	Identification of unit cost	Identify unit cost, equivalent unit cost, or lot costs by type and amount of material	Planning and Extensive quarter report reporting contingency budget
Company internal strategic pressure	Budget authorization; Management reporting	Internal reports (show budgets for each control account)	Having monthly meeting about financial update
Size of project team	OBS	Organization Breakdown Structure intersections with WBS	Detailed project team until the level of activity including subcontractor involved
High project schedule drive	Scheduling work; Calculate schedule variance	Distinct task using WBS to track progress, schedule variance	Variance and SPI updated monthly
Lack of Resource & Skills availability	Budget by cost elements; OBS	Resource Plan	Having detailed OBS to create detail distinction of workers and preferably working on site for all team
Lack of Experience with parties involved	Unauthorized revisions; Target cost goal;	Management performance reports	Creating backlog data record to client; Weekly meeting with external parties
Interfaces between different disciplines	Discrete work and objective measures	Control account/work package plans	WBS detailed into activity package
Number of financial sources	Accounting system and actual cost (scalability)	Actual costs report; Subcontract reported actual costs to payments; Internal and external performance reports for suppliers	Using tools as financial management (i.e. SAP); Having financial specialist; Database to monitor invoice
Number of contracts	Unit and lot costs; Track and report; Incorporate changes	Price change mechanism; Change mechanism	Adding variation register for change; extensive quarter report on change
Type of contract	Incorporate changes in a timely manner	Change mechanism	Implementation of change procedure and variation register required
Technical risks	Undistributed budget; Corrective action; Maintain estimate at completion	Planning for overhead budget and risk budget; Taking corrective action (duration); Updating estimate	Project risk measured by each project team using additional percentage to cover risk; Updating project estimate monthly
Organizational risks	Undistributed budget; Corrective action; Maintain estimate at completion	Planning for overhead budget and risk budget; Updating estimate	Include risk budget as percentage markup; Updating project estimate monthly
External risks	Undistributed budget; Maintain estimate at completion	Planning for overhead budget and risk budget; Updating estimate	Include risk budget as percentage markup; Include update on monthly forecast update
Uncertainties in scope	Project Scope (WBS)	Detailing WBS	Detailing work until activity package
Strict quality requirements	Corrective action	Objective completion criteria; Corrective action	Specified person to handle quality
Project duration	Schedule; Maintain baseline and forecast schedule	Schedule planning; Maintaining schedule and forecasting schedule update	In deciding duration and detailed until activity package; monthly update on schedule forecast
Size in CAPEX	Planned budget; Performance measurement baseline; Budget identification	Budget planning; Aspect in budget identification	Detail of budget planning until the level of activity package
Incompatibility between different pm methods / tools	Track and report; Allocation of indirect cost	Management performance reports; Cost collection structure	Implementation of backlog data and records; having weekly communication update with client
Dependencies on external stakeholders	Accounting consideration; Summarize performance data and variances for management reporting; Incorporate changes in a timely manner	Recording of direct and indirect cost; Report information and detail	Quarterly simple report for external parties
Number of external stakeholders	Accounting consideration; Summarize performance data and variances for management reporting;	Recording direct and indirect cost; Report change; Number of reports	Quarterly simple report for external parties and updating supplier rates

TOE Aspect	Related EVM Aspect based on ANSI/EIA-748 Standard	ANSI/EIA-748 EVM Scaled Aspect List	Added EVM Activity for Each High Element Score
	Incorporate changes in a timely manner		
High number of tasks	WBS; scheduling; identify products and milestone	Detail of WBS	Breakdown project until activity package
High variety of tasks	WBS; scheduling; determine discrete work and objective measures; level of effort planning and control	Detail of WBS; Work package plans; Responsibility assignment matrix; Resource plan; Internal reports; The amount of LOE	Detailing work until activity package, following an approval mechanism using formal document
Dependencies between tasks	WBS; schedule	Detail of WBS; Creating detailed objective on schedule and milestones	Implementation of daily progress report (DPR); one person to control each activity
Uncertainty in methods	Track and report material cost and quantities	Reporting results and trends	Daily meeting and report to update plan and tools
Involvement of different technical disciplines	Structuring schedules for progress status report and forecasting; Resource budget for future effort	Budget resource; Authorization work into organizational element	Regular re-measurement for calculation project budget quarterly
Conflicting norms and standards	Record allocation direct cost	Accounting Standards	Implementation of project dashboard tool on the trend of project going

On the basis of the mentioned analysis results, an EVM framework is developed with TOE complexity considerations as the method for grouping projects. Based on the activities performed by respondents in the project cases and taking into account the aforementioned factors, information is obtained regarding the activities that must be performed for each level of complexity.

This framework is utilized through a series of processes. Identifying the project with the TOE complexity questionnaire by assigning a score to each element is the initial step. After identifying the project, it is possible to see which element having a high complexity score. The next step is to modify any Earned Value Management activities mentioned in the guide to account for potential project complexity.

5. Discussion

Following an explanation of the methodology used and the results, this chapter will proceed to discuss upon the research findings in order to delve deeper into the suitability of this framework for Van Oord specifically, or companies with a comparable focus, as well as for the construction industry at large.

This chapter will focus on the analysis of the frameworks presented in chapter 4, exploring their applicability as a response to research question number 2 and 3. It will delve into their individual strengths and potential limitations, connection to the maturity level, as well as how they can be practically implemented, validated, and applied to address research sub-question number 4. Moreover, how these frameworks can effectively bridge the gap identified in chapter 1.1 will also discussed. This chapter further outlines implementation solutions, assesses their alignment with EVM maturity levels, and discusses the validation process involving experts.

5.1. Framework Analysis

The outcome of this study is a framework that incorporates both the ABCD project classification method and the TOE complexity analysis. Through correlation testing, although the ABCD project classification is a tool to measure project based on their risk, it has been determined that the ABCD project classification method is also associated with the concept of complexity compared to the TOE complexity analysis. Consequently, it can be inferred that the ABCD project classification method serves as a project sizing approach by means of project complexity analysis.

As discussed in the previous chapter, each project possesses its unique characteristics and varying levels of complexity. Consequently, it's crucial to recognize that no single project management method can fully predict all the intricacies of a project. However, to enhance effectiveness, it's important to identify and anticipate all pivotal aspects of the project as well as the EVM attributes to handle the project.

5.1.1. ABCD Earned Value Management Framework

One of the framework that emerges as a result is known as the ABCD EVM Framework (Table 14). The framework utilized in this study is derived from Van Oord's project sizing method, specifically known as the ABCD Risk Classification. Van Oord has implemented a risk assessment approach to categorize projects, wherein each project is assigned a value based on various elements associated with project risk.

According to the outcomes of the consultations with Van Oord, it is apparent that the development of this classification methodology was primarily intended to assist Van Oord in categorizing their projects. This categorization enables the identification of appropriate approaches for each level, thereby facilitating the determination of the most suitable method to be employed for projects at different levels within organizations. The initial step in developing this questionnaire involves a comprehensive analysis of over 70 past Van Oord projects. This analysis is further reinforced by engaging in a series of discussions with senior-level managers, particularly those associated with projects that serve as the case of this research. The objective of these discussions is to examine the various risk factors that impact the projects. The ABCD questionnaire incorporates several significant elements as the foundation for its inquiries.

The process of determining the answer options for each question and calculating the score follows a similar procedure. An analysis was conducted on multiple project datasets in order to determine the threshold for the answer to each of these questions based on the available case examples. Initially, the scores for each answer were distributed equally. However, after considering the outcomes of the discussion, a subsequent stage involved adjusting the scores based on the impact of risk factors on the project. The determination of the final threshold value, which is used to classify the ABCD aspect, is based on the cumulative value of each response option in the questionnaire.

Given the provided explanation, incorporating additional questions into the questionnaire may present certain challenges. The time required to modify the proportion of questions and answers in the questionnaire, followed by a comprehensive re-analysis of all project cases related to the topics to be incorporated into the questionnaire, required subsequent discussions with senior managers and final approval from the director level.

Hence, in order to incorporate the ABCD project classification as a project sizing technique within the framework, it is imperative to conduct an analysis to determine if the ABCD project classification can also be classified as a project classification method that accounts for project complexity. The findings of the correlation analysis conducted in Chapter 4.4 suggest a significant correlation between the ABCD project classification and the complexity of the TOE. Hence, the application of Earned Value Management scaling can be achieved solely through the utilization of the ABCD project classification aspect. This finding is also the answer to the research gap mentioned in chapter 1.1, where there was no research discusses how to make the EVM changed and adaptable to various level of project, as well as answering the research sub-question number 3 about the potential of modifying the implementation of Earned Value Management.

5.1.1.1. Explanation for Each ABCD EVM Framework Components

In the context of application and framework development, the approach employed adheres to the 10-step model of Earned Value Management, which encompasses a series of 10 different stages for the implementation of EVM. Subsequently, a prioritized sequence is established among the 10 stages, in accordance with the principles of Earned Value Analysis. This analytical approach entails the examination of three crucial components: Planned Value, Actual Cost, and Earned Value. The framework also completed by the other completing aspect in EVM such as related to reporting and deliveries, organization, responsibility assignment matrix, and analysis on changes.

In the following section, detailed explanations are provided for each component of Earned Value Management (EVM) across various levels. This comprehensive breakdown aims to offer a clear understanding of the intricacies and functionalities of each EVM component within its corresponding level.

- Planned Value
  The Planned Value element encompasses several components, such as the Authorization of Work Scope, Schedule Scope, Budget Scope, Planning Budget for Future Effort and Unmeasured Budget, Indirect Budget, and Management Reserve and Undistributed Budget.
  - **The Authorization of Work Scope:** This component related to the development of a Work Breakdown Structure. This procedure holds significant importance as it directly impacts the organization's budget planning and schedule planning. The scaling effort in this study involves modifying the size of the Work Breakdown Structure (WBS) to align with the specific requirements of the project. With the determination of the WBS level, the effort expended will be better aligned with the needs of the project. In the framework, the increasing aspect is on how deep does the WBS development should be. For level D, it is enough for the development until the level of control account, while for level C and B until the level of planning/work package, while level A need to be developed until the level of activity package.
  - **Schedule Scope:** Related to the strategic planning process employed by organizations in order to develop an effective schedule plan. A crucial initial task for small-scale projects involves the development of a schedule that defines an orderly sequence of work and establishes interdependencies among different segments of work. The sequence of project activities are required to all project levels. Within the established framework, projects characterized by high-level categories entail supplementary details, such as the incorporation of subcontractor schedules into the master schedule, as well as the utilization

of probability estimation of other unmeasured activity outside production estimate. On project level B and C, the difference is on the role of dedicated project scheduler to be on site and controlling on critical project schedule and equipment's cycle time. On project C, the role of analysing critical schedule can be handled by project manager. While for project D, the minimum effort that can be done is by creating the project schedule plan using estimation for each of the activity.

In addition to the development of a schedule plan, there is also an ongoing effort to scale the integration of project duration at the level of Work Breakdown Structure (WBS) detail. This initiative aims to facilitate the monitoring of project progress by control accounts. The final product includes project milestone to examine strategies for organizations to effectively partition their projects into multiple segments. It is advisable to incorporate a more condensed series of milestones for projects that exhibit a significant degree of complexity. The terms of milestone here following the sequence of reporting actual and financial cost (Weekly for level A, monthly for level B and C, while for level D following what been set on contract)

- **Budget Scope:** This component related to the project's approach in effectively overseeing the comprehensive planning process for the project budget. Indeed, it is necessary that all stages of project planning handle comprehensive considerations of various factors that impact the project budget, including but not limited to materials, utilization of equipment (specifically vessels), labour hours, and other operational requirements. The scaling method aligns with the hierarchical structure of the Work Breakdown Structure (WBS) to enhance accountability and cost estimate classifications.

  Regarding the classification of cost estimates, assuming that projects at each level are projects that have already been awarded with some project information already available, the project budget estimation for level D projects can be done using the Class 3 estimation method (with a semi-detailed or predefined unit cost and assembly line items methodology according to the WBS level). For level B and C projects, the Class 2 estimation method can be employed (with detailed unit cost based on the WBS level and forced detailed take-off or assumptions about several undefined aspect). Meanwhile, for level A projects, the Class 1 estimation method is used (with detailed and specific cost estimation for each activity).
- **Budget for Future Effort and Unmeasured Budget**: This component related to budgets that cannot be predicted when doing budget planning. The scaling aspect is implemented by employing a consistent percentage rate for project level D and utilizing calculations for each activity, adopting a potential budget change approach for project level A. In between, the difference of project level B and C is on the product of the planned budget. It is advisable for level B to do tax planning and calculation so the increased rates are more precise than only applying percentage markup.
- **Indirect Budget**: This component related to budgetary considerations that are not subject to direct monitoring of purchases, such as project overhead, utilities, insurance, and other elements that are not specifically allocated within direct costs (Government of the Netherlands, 2021). The process of scaling is implemented through the application of fixed costs for level D projects and the calculation of percentages for level A projects. In between, project level C may again use the concept of percentage mark up on overall budget summary, while for project B suggested to do it on each of the activity considering the consumables and the complexity of equipment used.
- **Management Reserve and Undistributed Budget**: This component related to specific risk financial allocations within an organization. The management reserve is a designated amount of funds set aside to address unforeseen events or risks that may arise during a project or the budget allocation pertaining to the contingency funds for potential risks within the project. The applied scaling approach involves taking into account the project's

scope, as the inclusion of the budget aspect may not be necessary in cases where the project risk is minimal or the work scope is easily determined. The process of scaling is implemented by employing the risk measurement approach at every level of the project.

- Actual Cost

  Aspects monitored in Actual Cost relate to the method of collecting actual cost updates and what aspects are monitored (such as materials in projects), and how financial conditions should be updated.

  - **Reporting Actual Costs**: As outlined in the ANSI/EIA-748 standard, the methodology to scale this component is by establishing a comprehensive reporting system that is structured according to the Work Breakdown Structure (WBS) level. Moreover, in the absence of an established accounting system or dedicated survey team, it is still possible to generate accurate estimates for small project which means that by comparing actual spending with the progress seen on site. The scaling process for this particular point in the ABCD EVM framework involves the collaboration of the survey team and entails providing comprehensive reporting at the Work Breakdown Structure (WBS) level. In this aspect, project level B and C having similar method due to the similarity method in applying WBS and suggested to have survey team to survey the more comprehensive update including the material stock and used or any other progress in detail.. While for level A, it is suggested to have integrated system where the trend (Actual vs plan) of the project also automatically updated after the data of the project progress have been recorded.
  - **Accounting System for Materials**: The scaling of reporting actual costs can be achieved by employing reporting methods for material updates. The employed approach for scaling involves making adjustments to both the reporting methodology and the utilized system. In the context of small-scale projects, employing a basic financial spreadsheet proves to be sufficient such as Excel, while the report contains sufficient information to communicate the essential components of the critical material on the project. However, for a more complex project, it is necessary to implement a comprehensive reporting system (i.e. Budget Cost Report, Cleopatra). For level C, the focus can be limited to only critical important element due to limitation in resource, while for level B, all aspect should be reported. In project level A, change and procurement also suggested to be reported regularly to monitor change.
  - **Updating Financial Conditions**: This component related to periodical reporting financial conditions for internal/external reports and corrective actions. In small project, it is enough to have quarter financial update, while for a more complex project, with the potential of having bigger risk and impacted to project budget, the financial condition need to be updated more often. Furthermore, for level A projects, especially when there is a Joint Venture (JV) or partnership arrangement, it becomes necessary to provide more frequent updates on the project's financial condition. This is because the increased potential for risks necessitates more regular communication. With the possibility of significant variations in project progress on a daily basis, creating weekly updates will reveal trends and potential risks related to the financial situation. This allows for swift corrective action to be taken in response.

- Earned Value

  This section discusses various elements related to the Earned Value calculation method, including the collection of achievement data, reporting on variance, and forecast calculations.

  - **Quantification of Worth The Work to Date:** This component related to determining project milestones. The assessment of the value of the work conducted thus far in relation to the identification of project milestones. The delineation of project milestones is typically outlined within the contractual agreement established by the client. However, in

the context of scaling methodology, it is possible to generate interim milestones within the project. In the case of small project, it is feasible to assign a percentage of accomplishment based on the attainment of all project objectives.

However, for projects of bigger size, it is advisable to establish milestones and employ quantifiable supporting data, such as metrics for measuring project progress. Monitoring can be facilitated through the utilization of various tools, including the S-Curve, as well as the assistance of a survey team to collect actual data. In calculating Earned Value, formula method (formula 8) can be utilized to measure the progress of the project. Additionally, in project level A, the project traffic also can be useful which refers to the condition of the project whether it is in red condition (dangerous or critical), yellow (medium), or green (safe). This is useful for the project manager to have instant update on the project.

In terms of updating period, the earned value should be included on the weekly trend report to monitor the achieved activity and budget spent, while for the calculation should be included on the monthly report, for instance in project level D, the milestone achievement should could be updated monthly, as well as updating the S-Curve for project level C, B, and A.

- **Reporting Variance:** This component holds significant importance within the context of Earned Value Management. This variance serves as a crucial indicator for assessing the condition and status of a project, enabling project managers to gather pertinent information necessary for determining appropriate corrective actions. The process of scaling is accomplished by implementing a variance report period, during which various aspects of the project variance are closely monitored (Cost and Schedule). However, based on the interview performed, all level of project have the same period on reporting variance which done monthly. This is because generally also set in ANSI/EIA-748 that variance calculation usually done monthly for showing a specific increase in the progress of the project. But, there are slight difference on how to monitor the variance. In project level A, the implementation of Bullseye diagram (figure 4) can be useful to monitor the movement of the schedule and cost variance. Cumulative variance refers to the whole update on project budget and duration, while for critical variance should be controlled per work package level.
- **Project Forecasting**: This component follows the determination of project variance, however in project level A, cost update can also be monitored weekly especially for the project who has tight milestones. The estimation at completion calculations can be conducted through the scaling method, which involves forecasting calculation periods. Besides that, utilization of CPI and SPI concept are necessary to be applied on all level of project since it serve as the basic implementation of Earned Value Management. Variation of forecasting formula mentioned in chapter 2.2.2 can be used in different project level, for instance in project level D, calculation on forecast is sufficient by only using the generic EAC formula (Formula 5) or the by using the dividing BAC to CPI formula, while for the higher level, it is preferred to use a more complex calculation (Formula 7. EAC formula calculation if the remaining work will be performed as planned).

- Project Goals

  This component is still included in the framework because it is part of the 10-step model. In addition, Project Goals are one of the important elements in the project that must be understood by the entire project team. However, there are no aspects that can be scaled from the content of project goals, but aspects that can be scaled are the methods for achieving these project goals through the application of other attributes in Earned Value Management such as having detailed WBS, consistent deliveries, effective on updating project progress, and other.

- Organization Breakdown Structure
  The aspects that are monitored in the OBS include recommendations pertaining to the composition of the project team and the utilization of OBS as a structural framework within the project.
  - **Project Team Member**: This component is closely associated with the concept of organizational composition, which pertains to the determination of the optimal team size required at various levels of a project. According to the findings from the interview, it is indicated that at project level D, the involvement of a limited number of individuals from the headquarters suffices for the project site. However, as the project level increases, the number of teams involved also escalates. Even at project level A, it is advisable to incorporate a subcontractor in the systems planning process.
  - **Organizational Breakdown Structure**: This component suggest the implementation of organization structural system. The OBS is not needed for low-level projects due to the limitation of team involved, but is required for higher-level projects that are aligned with the WBS. This serves to assist the process of monitoring and responsibility analysis.

- Responsibility Assignment Matrix
  In this component, things that are highlighted and can be scaled are the workflow and communication chain, responsibility to subcontractors or external parties, and taking corrective action.
  - **Workflow of Working:** This component related to the communication chain. For low-level projects, simpler approval is sufficient by sending regular report to project manager (level D), however for level C, the project manager need to be well informed with what included on the report. In project level B, the project manager also actively gathering all the information to report regularly to the business unit. While for project level A, approval mechanisms and formal documentation are required to record all changes.
  - **Handling on Subcontractor**: This component is necessary in order to enhance the clarity of ways to communicate with subcontractors, as and when required. In projects of small scale, if the presence of a subcontractor is existed, then it requires the assignment of at least one individual to oversee its operations. In project level B and C, project manager having responsibility on handling subcontractor, while in project level A, subcontractor advisedly to be involved on the project structure to also have connection with other team member.
  - **Handling Corrective Action:** The necessity of taking responsibility for implementing corrective measures is also essential when employing Earned Value Management, as such actions can facilitate the project's alignment with its initial objectives. The process of achieving scalability involves the identification of the appropriate person responsible for determining the necessary corrective action.

- Results and Deliveries
  Results and deliveries are related to reporting methods and documentation. This component will discuss about regulation in changes, preparing summarized information for management, reporting indirect costs, and reporting subcontractor activity.
  - **Change of Performance Measurement Baseline:** The concept of regulation in change refers to the essential elements that need to be present in order to proactively anticipate possible changes to the Performance Measurement Baseline. The aspect of scaling in this particular case pertains to the approval chain and documentation of the implemented changes. All changes need to be reported weekly to all project level. Meanwhile, in the change procedure, in project level D the project manager can decide what to do, but project

level B and C require change procedure, even in project level A, variation register to record change need to be implemented beside applying change procedure.

- **Summarizing information for Management Evaluation**: This component explains how the progress of the project should be reported and what information might be useful for updating project trends. For low-level projects, all information must be reported quarterly to be reported to management. Meanwhile for higher projects, added aspects such as market update information and price changes must be reported. This is because high-level projects tend to have quite a long duration so that information about market changes must also be reported.
- **Reporting Indirect Cost:** Reporting indirect costs must be reported at all project levels correspondently with budget report. This is because indirect costs play an important role in determining the updated project budget and should be included on the management report. The thing that can be scaled from this aspect is who should provide the indirect budget report and the procedure of reporting chain which has been explained in the Responsibility Assignment Matrix point.
- **Reporting Subcontractor Activity:** The activity of reporting subcontractor updates is valuable in gaining insight into the actions of subcontractors that may impact the project's efficiency. Subcontractor activities are closely tied to project budget allocation and expenditure. Consequently, it is advisable to implement a reporting system that encompasses the flow of information. For smaller-scale projects, it is sufficient to monitor subcontractor activities at the control account level. However, for larger projects, it is necessary to include activity-level reporting, aligned with the Work Breakdown Structure (WBS) hierarchy.

- Analysis
  This attribute relates to actions that can be undertaken following receiving of project updates and is associated with Earned Value Management, specifically the implementation of Change Management, which encompasses change control boards and baseline change requests.
  - **Baseline Change Requests:** This part related to tools that can be used to anticipate changes in the project. The mentioned tools include a variety of functions, spreading from basic log systems that track modifications made to documents, to the implementation of structured workflows and dashboards that facilitate the monitoring of said changes.

Some of the activities provided in the framework mostly have similarities especially for project level B and C. This is because generally in terms of complexity, as seen from Table 13, both project B and C share almost similar range in terms of each elements of TOE, therefore the identity or characteristic mostly are the same. Additionally, it is also validated with the result of the interview where both project levels having the same EVM approach.

The activity stages determined from interview findings at each level serve to validate the activities proposed by ANSI/EIA-748 for projects at the lowest tier. Correspondingly, the arrangement of attribute subcategories is guided by interview outcomes and participants' understanding. This adaptation addresses the identified gap and research sub-question 3 concerning the feasibility of adapting Earned Value Management to different project levels according to their complexity.

Regarding the EVM maturity level, this framework contains recommendations for activities based on the organizational conditions originating from EVM maturity level 1. However, the information provided pertains to project monitoring in a general sense. Then, this information is distilled within a framework that adheres to the minimum standards of Earned Value Management. It applies several concepts from Earned Value Management with higher maturity levels. Moreover, despite the maturity level, the scalability aspect of the EVM are shown in the framework showing that maturity level is not really affecting the potential of scaling the attributes of the EVM towards the different levels of

the project. Consequently, by implementing this framework across all projects owned by Van Oord, it is an effort to elevate the maturity level to higher levels. This will be achieved through comprehensive application phases and by following scaling suggestions based on ANSI/EIA-748, which also encompasses indirect material planning and the application of control account level. According to Table 1, this corresponds to EVM maturity level 3. This findings aligned with the concept discussed by Nkiwane et al. (2016), who found a correlation between enhancing EVM and increasing project management maturity.

5.1.1.2. Advantages and Disadvantages of ABCD EVM Framework

Despite the function and adaptability of the framework, this framework also has its advantages and disadvantages which are:

- This framework has a clearer and more consistent form
  The EVM framework, which uses Van Oord's ABCD project classification, has a more consistent form because it follows the 10-step Earned Value Management model (Antvik & Sjoholm, 2012). In addition, the project classification method is also more consistent and general where projects are classified into 4 levels only, namely levels A – D.

- This framework is practically applicable specifically for Van Oord.
  The utilization of the classification method employed in this study is attributed to its development by Van Oord. Consequently, this approach streamlines administrative processes by employing a singular questionnaire for project grouping, thereby enhancing efficiency. Moreover, for Van Oord, a company in the early stages of implementing Earned Value Management as its system, the adoption of this system offers the advantage of simplicity, thereby facilitating its implementation process.

- ABCD method is not specific
  As previously stated, the ABCD method is employed to categorize projects into four distinct levels. In theoretical terms, it can be argued that every project has a unique character and consists of crucial elements. Therefore, when categorizing this project, it is possible that certain elements may not be considered initially, yet they may ultimately contribute significantly to its overall impact. For instance, in the case of a project categorized as Level D, it is possible that certain critical aspects such as schedule and project team size, which hold substantial influence, may not be adequately addressed in the ABCD questionnaire. Consequently, if these aspects remain undetected through the employed Earned Value Management method, the project will be exposed to potential risks.
  A possibility to improving the ABCD project classification method involves the incorporation of additional inquiries. However, this effort creates challenges due to the extensive repetition of the process, prior modifications to the organizational system, and the need to ascertain the appropriate questions for acceptance.

- This framework specifically served for Van Oord
  The applicability of the project classification method utilized in this study, developed by Van Oord and based on criteria derived from a selection of Van Oord's own projects, may present challenges when attempting to implement it in organizations lacking a similar classification method with Van Oord. Nevertheless, the activity approach outlined in this framework demonstrates a generic implementation of Earned Value Management. As a result, it can be applied to organizations that possess similar classification structure.

5.1.2. TOE Earned Value Management Framework

Another framework that was created is one that uses TOE complexity to identify projects. This method generates a framework in the form of a guideline to create a to-do list of Earned Value Management activities. These activities can be implemented to proactively address elements of Technical, Organizational, and External factors that possess significant criticality or have the potential to evolve into high complexity within a project. This framework also serves to patching a hole from the ABCD EVM framework regarding the uncovered critical complexity elements.

As outlined in chapter 4, the Earned Value Management framework incorporates a set of 29 complexity elements. These elements, which possess a significant correlation and impact on the application of Earned Value Management, are carefully selected and integrated into the framework. The correlation between these elements is assessed by examining the literacy outcomes of the 32 stages of the Earned Value Management application, as outlined in the ANSI/EIA-748 standard (NDIA, 2018). Additionally, the scalability aspects of Earned Value Management are evaluated based on the guidelines provided in the ANSI/EIA-748 standard (NDIA, 2020).

The sorting process is conducted through a series of procedures in which the elements of TOE complexity are analysed, scalability aspects are comprehended, and the attributes of Earned Value Management mentioned in the literature are defined. The activity of conducting Earned Value Management analysis is followed by an analysis of each of these components to determine the related attributes and the end result of these attributes.

There are multiple elements among the 29 elements of project complexity that have the same product, but have the potential for different complexity scores. Hence, the decision regarding the activities to be undertaken is based on the principle of aligning them with those performed at a more advanced level of complexity, in order to ensure safety.

The utilization of the TOE EVM framework (Table 15) is contingent upon its alignment with the specific requirements and circumstances of the project at present. The initial step in effectively utilizing this method involves the identification of projects through the utilization of the TOE questionnaire. Subsequently, the 29 TOE elements associated with Earned Value Management are to be categorized. Afterwards, a set of Earned Value Management activities is chosen from each of these elements to proactively address potential complexities. Due to the fact that the purpose of this framework is to improve the ABCD EVM framework, the activity suggested on the high complexity level then combined and adjusted with the current activity on the ABCD EVM framework.

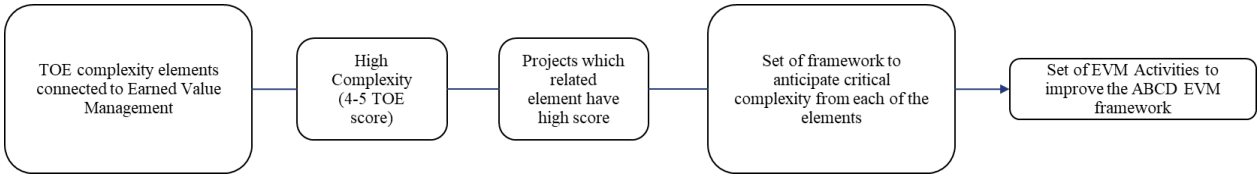


Figure 19 Methodology of using TOE EVM framework

The use of TOE complexity elements by only focusing on critical elements is because if the element analysis is at low and medium values, then it is sufficient to use a framework based on the ABCD project classification. Thus, TOE Complexity here only focuses on patching critical elements that are not covered by the ABCD project classification.

Nonetheless, a framework based on TOE complexity actually can be generated using a similar method by adding a set of activities to cover each TOE complexity element, including Low Complexity level and Medium Complexity level. However, this framework has multiple weaknesses. There is no complete set of EVM model (such as the 10-step model in the ABCD EVM framework) because this framework is merely a suggested activity for addressing the 29 element complexity associated with

EVM. If attempt made to apply a set framework (such as a 10-step model), some attributes will be missing because there might be some EVM attribute which not related to the TOE complexity elements. In addition, because TOE complexity cannot be assigned to one single project value, it is challenging to implement a set framework because project levels cannot be stated.

A further disadvantage of this method is the inconsistency of its application, as each project may have a different EVM method based on the nature of the project (determined by the TOE complexity assessment element value), making it difficult for organizations to implement standard Earned Value Management applications.

5.1.3. Implementation of Both Frameworks

Despite the fact that it is known that the two frameworks have their respective functions and advantages, the two frameworks still have deficiencies in terms of effectiveness. Two distinct types of frameworks were developed for this study, the first of which is the pragmatic ABCD EVM framework for case studies at Van Oord. To make this framework more effective, however, improvement activities are performed on critical elements by using TOE complexity as a classification method for projects, and additional activities are obtained from the EVM framework by using TOE as a classification method for projects.

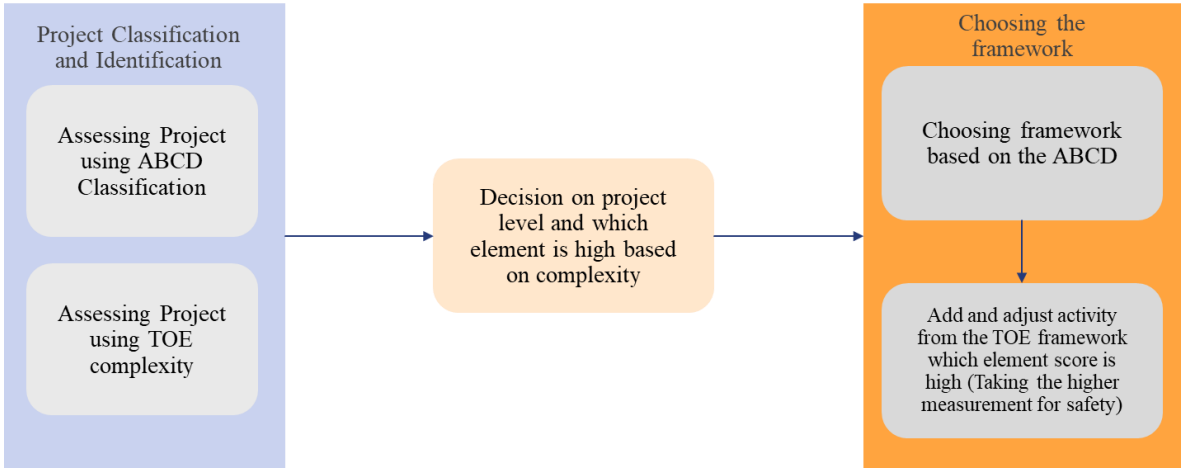


Figure 20 Procedure of Framework Application

Utilization of this procedure can create a more applicable method since the classification used is the ABCD project classification, which is a system developed by Van Oord; its use is more practical and consistent because for each project level there is a set of guidelines for Earned Value Management applications and a more consistent activity list. In addition, Earned Value Management's application can be enhanced with the TOE complexity framework in order to address questions regarding unfulfilled critical aspects of the ABCD project classification method. Therefore, projects with various type and complexity can be widely covered by using this framework.

However, in terms of applicability both frameworks, some activities may contradictory to one another. Therefore, if several contradictory or overlapping activities are discovered between the two frameworks, the activity with the higher intensity is selected as a preventative measure to anticipate potential project complexity.

In broad terms, effectively adapting the framework to diverse projects involves the following steps:

a. Begin by employing the ABCD questionnaire or a similar project sizing questionnaire to categorize projects into several levels (preferably 3 or 4 levels).
b. Utilize the TOE complexity assessment to encompass intricate project complexity aspects that may have been overlooked.

c. Choosing the EVM procedure following the ABCD EVM Framework following the levels (for project with 3 different levels, choosing the application of EVM for level B can be considered)
d. Enhance the EVM activities by integrating select improvements from the TOE EVM Framework to optimize the execution of EVM practices.

5.2. Validation

After the development of this framework, the validation procedure has been done. The validation process consists of two processes: group meeting validation with three experts and company supervisors, followed by individual meetings with each of these experts, and validation of the potential for ABCD project classification as a method for project sizing in order to establish the EVM framework.

The first step was to validate the framework through a 60-minute group meeting. This meeting was attended by some experts from Van Oord to discuss the preliminary research findings. In the first 20 minutes, the initial findings has been presented and their potential application has been discussed. Based on the outcomes of the discussion, the following points have been derived from this validation:

- Based on the results of interviews and analysis, it was determined that the EVM maturity level to the selected projects was estimated at level 1; it was also being validated with the feedback that although the majority of the project cases had employed Earned Value Management monitoring, it is not yet applied in every Van Oord project. Therefore, according to the validation procedure, it is assumed that the organization is at the first EVM maturity level.
- During the creation of the framework, it should be possible to arrange activities that have a significant impact on the Earned Value Management application in relation to those that do not. On the basis of the results of this validation, the ABCD EVM Framework arrangements are subdivided into activities included in Earned Value Analysis and supporting activities that are part of the Earned Value Management System.
- It was feared that some of the framework's activity points were too specific, will lead to an overuse and stirred use of framework. Furthermore, not all projects in the same level category carry out activities with the same level of detail as specified in the framework; therefore, the framework's guide activities are made more general and practical.
- Several points in the framework have the same activity solution, making it impossible to see the scaling. This is because the monitored aspects are less specific and too general, so the solution is to make the monitored aspects more specific by adhering to ANSI/EIA-748.

The following week after this group meeting, a second validation was performed on each participant by displaying a framework update. In this personal meeting, it was determined that the way of approaching the result of this research had sufficient and logical reasoning. However, for the framework it needs to be more precise in presenting the scaling aspect.

5.3. Recommendation

This section will discuss the study's recommendations for the construction industry in general. In this chapter, suggestions regarding the application and utility of this research are also explained.

5.3.1. Recommendation for Construction Industry

This research was conducted at Van Oord, a company engaged in Marine and Offshore Engineering, where the scope of the dredging project and the offshore windmill installation project served as the study case. However, the frameworks resulted maybe useful for other organizations that employ Earned Value Management, as the project cases in this study also entails a variety of general construction works. In addition, the approach method used to develop the Earned Value Management framework was derived from interview questions about project monitoring methods for the

construction industry, which in this study is the construction industry in the field of Marine and Offshore Engineering. The applicability of the ABCD EVM framework (Table 14) can be useful for organizations who has typical project sizing to classify their projects. This framework is versatile enough to accommodate both four-level and three-level project sizing. The ABCD EVM framework has been structured to adapt the Earned Value Management approach to these various project scales, where the two medium-scale projects share similar conditions.

Specifically when using the TOE EVM framework (Table 15) in which the project classification method scales the project based on the TOE project complexity. The TOE complexity method is an academically validated method for identifying project types, allowing the TOE EVM framework to be utilized more broadly. The TOE EVM Framework can be utilized by other organizations that have implemented Earned Value Management to evaluate and enhance their Earned Value Management.

The development of the framework composition also incorporates the concept of the 10-step model, which is a concept obtained from academic journals and the ANSI/EIA-748 standard as the standard for EVM application. The suggested activities also encompass general aspects of project monitoring, but they should ideally be adjusted according to the regulations and practices of the company in utilizing monitoring tools.

6. Conclusion

This chapter will discuss the conclusions that address the Research Question by addressing each of the Sub-Research Questions posed in this study. In addition, suggestions for future research will also be discussed.

6.1. Conclusion to Answer Research Question

In this subchapter, the study's conclusions will be discussed in response to the research questions posed in Chapter 1. The study's research questions is:

"How to adapt Earned Value Management to various levels of projects based on the project complexity?"

However for the answers to the sub-questions are:

1. **What are the significant elements in Earned Value Management?**
   The concept of Earned Value Analysis, which includes Planned Value, Actual Cost, and Earned Value, is an essential element of Earned Value Management. Significant elements of Earned Value Management must at a minimum be sufficient to conduct variance analysis to compare what was planned in terms of time, cost, and scope with actual project achievements. Several support attributes are required to facilitate the Earned Value Analysis process, which in this study adhere to the EVM 10-step model concept, where in addition to the three mentioned factors, there are other attributes such as determining project goals and scope, WBS application, OBS, RAM determination, updating method information and deliveries, and analysis on taking corrective action. The selection of the 10-step model is regarded as more general and comprises all Earned Value Management characteristics.

2. **What is the maturity level of organization in applying Earned Value Management?**
   Based on the results of the analysis comparing interview responses and the EVM maturity level theory, also validated through interview, the organization is currently assumed to be on EVM maturity level 1. Maturity level can influence and be influenced by the Earned Value Management application framework, where based on the findings of this study, it is validated from interview responses that there are limitations to variations in the use of Earned Value Management aspects, where a number of specific EVM elements are not mentioned or utilized. However, despite the maturity level condition, various adaptation of Earned Value Management are shown in the framework towards different project level, which indicating that the potential of scalability is not affected by the maturity level, instead this framework can be utilized as an endeavour to enhance EVM maturity levels. This is attributed to the framework's applicability across thecompany's entire project and its incorporation of several components from EVM maturity level 3, such as indirect EVM planning and compliance with the ANSI/EIA-748 standard.

3. **How can the application of EVM change based on the complexity of the project?**
   The customization of Earned Value Management in alignment with ANSI/EIA-748 involves the adjustment of a subset of its EVM variables. The outcomes of the conducted interviews have also unveiled distinctions in the application of Earned Value Management across diverse project types. The adaptation of Earned Value Management, as revealed through this study, can be achieved by stratifying projects into distinct levels and tailoring its implementation to each such level. The categorization of project levels hinges on the organization's project sizing methodology which impacting to the modification of the Earned Value Management framework.
   For each project level, a comprehensive guide for Earned Value Management is formulated. This guide is meticulously crafted through the assimilation of fundamental directives outlined

in the EIA-748 standard, as well as the attributes delineated within the sorted EVM 10-step model as shown in table 4. Employing this approach, a diverse array of activities corresponding to each EVM attribute has been discerned for implementation within the organization. As shown in table 14, variety of EVM application on each of the project levels are resulted including distinct Work Breakdown Structure (WBS) levels, budget planning methodologies, earned value calculation protocols, reporting mechanisms, and the formulation of corrective actions and adjustments. This diversity also serves to address the research gap by demonstrating the adaptability of EVM to complexity and its potential customization across various project levels. In the meantime, the Earned Value Management activity for the TOE EVM framework shown in table 15 generates guidelines to anticipate the complexity potential of the project.

4. **How can EVM be practically adapted to different projects based on their level of complexity?**
   Based on validation results mentioned in chapter 5.2, achieving effectiveness in the practical adaptable of the EVM framework requires the initial identification of Earned Value Management aspects that align with industry standards for scalability. In this study, the scaling process follows the 10-step model, with particular emphasis on Earned Value Analysis, encompassing Planned Value, Actual Cost, and Earned Value. To operationalize this framework, the application of each activity at every level should exhibit distinct variations. Level D projects, typically less complex than Levels C, B, and A, necessitate specific scaled attributes. These attributes are outlined within the framework, showcasing the tailored scaling activities for each EVM attribute based on interview insights and theoretical analysis.
   Furthermore, the adaptation and combination of the two frameworks must be executed by employing the ABCD EVM framework as the foundational structure. This approach ensures a consistent and lucid framework for use across all levels. Simultaneously, the TOE EVM framework can be employed to supplement certain elements not encompassed within the project sizing method, as determined by the ABCD project classification. Consequently, the resulting enhanced ABCD EVM framework becomes more effective and precise in its ability to anticipate potential critical elements within projects.

6.2. Research Limitation

This sub-chapter will discuss the limitations of this research which can be taken into consideration for further research.

- This research was only conducted over a period of 6-7 months; therefore, there was insufficient time to test the applicability of the framework resulting from this study. This results in several aspects that have not been validated, as the only way to validate this framework is to compare and test it against the actual project to determine whether it provides accurate information and makes work more efficient.
- Additional research limitations include the limited number of respondents and the provided case examples. This is due to the difficulty of finding respondents relevant to the topic under discussion and the limited time provided by the respondents. In addition, the number of projects discussed was limited due to the fact that multiple respondents worked on the same project. Therefore, if the number of projects and respondents can be increased, the information regarding projects and case studies can be more diverse, resulting in more accurate framework activities.
- The subjectivity of the study produced by this research is another limitation of this research. Due to the fact that this research was conducted by a single researcher, judgment and

interpretation hardly depend on a single individual. Particularly in the selection of quotations, coding, and comprehension of the transcript are limited by the researcher's subjectivity. In addition, the questions asked were of broad scope regarding project monitoring, with the assumption that the respondents did not fully comprehend the aspects of Earned Value Management in detail; therefore, there was a chance of error in translating and interpreting the interview results into each element of Earned Value Management. In addition, the author's logic limits the selection of activities and scaling up methods. In order to circumvent this limitation, data triangulation can be used to reduce the possibility of subjectivity.

- In addition, the length of the interview is a limitation of this study. This is due to the respondents' schedules and the large number of questions, which necessitated a short interview duration. The interview lasted one hour and consisted primarily of questions, some of which were not explored in depth due to time constraints. Due to their short duration, a number of projects do not have a classification for the ABCD and TOE dimensions of complexity. Ideally, this questionnaire should also be completed during the interview so that the respondent understands what must be filled out and the researcher can verify that the questionnaire has been completed. Therefore, the solution is to extend the duration of the interview by discussing the duration with the respondent well in advance of the interviewing process.
- The respondents' subjectivity in completing the questionnaire is another limitation of this study. Respondents completed the questionnaire for ABCD project classification and TOE complexity independently, with the exception of one respondent who did so through discussions with one of his colleague. Even though this filling is based on the actual project case and expert judgment, the questionnaire would be more accurate if it were filled out by the whole project team.

6.3. Recommendation for Future Research

Recommendation for further studies on the scalability aspect of Earned Value Management gathered based on the findings and limitations of this study. As a recommendation for future research, the scope of the projects and industries used as framework case studies should be expanded. This can be done to enhance the framework's activity options and the accuracy of its information. This study recommends testing the framework on projects other than the Van Oord projects to determine its general applicability.

In addition to this research, the effectiveness of the 10-step model can be evaluated by determining whether the 10-step model has covered key aspects of Earned Value Management and by establishing a connection between the 10-step EVM model and the ANSI/EIA-748 standard EMV guidelines. Another thing that can be done is to create a standard project levelling classification based on TOE complexity as a modifier so that a more consistent method for project levelling based on an academic approach can be developed.

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Appendix

Appendix A. Interview Protocol

Introduction

- Thanking the participant for attending the interview
- Introducing Interviewer
- Explaining the research background and the objective of the interview
    - Gaining information on the application of project monitoring tools
    - Gathering the understanding of Earned Value Management as Monitoring Tools
    - Gathering the information about project complexity and how experts handle project
    - Gaining information on how to categorize project
- Explaining the duration and structure of the interview
- Request to record the interview
- Assuring the participant's anonymity in the report, not publishing the record, making it only available to research staff, and planning the deletion of recordings
- Ensuring not to give information if considered confidential
- Ensuring that the participant sign the informed consent form
- The notes of the meeting will be sent to the interviewee and will be confirmed or added if necessary

Interview Date :

Interview Details:

- Name :
- Email :
- Job title/Position :
- Years of Position :

EVM Scalability

Introduction

1. Can you introduce yourself?
2. How long have you worked in this field?
3. Could you tell me about at least three different types of projects you have worked (small, medium, large) on in the past and the role you played in each of them?
4. Can you give a slight detail on the project you have been involved in?
    - Name
    - Location
    - Size and Scope
    - Stakeholder involved
    - Internal team involved
    - Possible risk faced
    - Duration
    - Cost

Project Monitoring

5. What aspects do you think are important in monitoring projects?
6. What aspect do you think is not necessary to be applied based on the experience you had?
7. Can you tell me the tools you used to monitor your projects?

- Follow-up question: Do you have an integrated system defined by the uniformity of the language used and easy access to analyze the data?

8. What were the problems you faced during the implementation of the monitoring tools you used, and how did you overcome them?
9. What are the differences you applied to the monitoring tools for your different projects?

Organization

10. Are you familiar with the work breakdown structure? Are you using it to as your monitoring tools? If yes, at which level do you usually use the WBS?
    - Is it effective? Do you think using a lower WBS level would make your project more effective?
    - If no, what kind of standard breakdown structure you use?
11. To whom do you assign project activities? Does it go per person, team, or division?
    - Do you think it is effective?
12. How is the communication between teams or activities going?
    - Do you think the communication style you use is effective?

Project Schedule

13. What are the resources for schedule planning during planning phase?
    - Are you using a historical database or production estimate?
14. How do you set the objective's milestones for the project?
    - Do you use the concept of the Critical Path Method (CPM)?

Project Budget

15. What are the resources for budget planning?
16. How do you handle the situation of price differences, taxes, and inflation when deciding the project budget? Is it part of your consideration?
17. How do you consider indirect costs (salaries and operational costs) in project planning?
18. How do you monitor the purchases in the project and the quantity used for resources, materials, and consumables?
19. How do you monitor the forecast at completion?

Results and Deliveries

20. How often do you monitor the progress of your project (have a progress meeting)?
    - Do you find it is effective?
21. What data do you usually receive in the progress report?
22. What data do you want to be reviewed and learned about in the progress report?
23. How do you translate your progress into earned value?

Analysis

24. How often do you calculate project variances and forecast them at completion?
25. How do you measure the possible risk of your project?
26. Have you ever encountered a problem where you had to face changes in terms of project scope, timeline, or resources?
27. What is the reporting chain for sending information about changes in the project?
28. If an incident occurs, who makes the decision for the corrective action, and how long does it take until the solution results?

29. In general, what do you think about your monitoring tools, and what are your wishes to be added to them that you think will make the monitoring more effective?

Project Complexity

30. From your perspective, what does complexity in a project mean? Have you ever faced it in one of your projects?

EVM maturity level

31. Are you familiar with earned value management?
    - Are you familiar with the ANSI/EIA-748 Standard Guidelines for Earned Value Management?
    - If yes, are you applying those standards to the current EVM you implement?
    - Are you currently in the EVM development phase?
    - Can you explain how far you apply your current, developed EVM?
    - How many people have you assigned to handle the development of the EVM?
    - How far is the development of this EVM currently going?
      Choose one of the following terms to answer question number 6:
      - Basic application (10 basic EVM steps)
      - Fully following the ANSI/EIA-748 guidelines (32 steps of the ANSI/EIA-748 standard in implementing EVM)
      - Having EVM logs and a repository and currently advancing the EVM framework

32. Do you have feedback towards this interview?

Appendix B. Definition of ANSI/EIA-748 Guideline

a. Organization

Several attributes are explained in this part. First is defining the authorized work elements for the program through Work Breakdown Structure (WBS), Organization Breakdown Structure (OBS), Process Integration, Overhead Management, and Control Accounts. The WBS and OBS are the main components in the organization aspect. Usually the WBS will produce the statement of work (SOW), which consists of the elements of technical, schedule, and cost information, and then the OBS will look at the available members of the organization who have the skill to fill the position. Process integration is the combination of both WBS and OBS. This combination will create a Performance Measurement Baseline (PMB) to identify progress, actual cost, and corrective action if required.

Overhead Management assigns the company function responsible if overhead occurs (in terms of indirect cost). Usually, the deciding manager is assigned to control these costs and approve expenditures if necessary in terms of the EVM organizational aspect. Lastly, the control accounts help to detail the complexity of work and the capabilities of the organization. Moreover, it can also help to determine the details of the budget structure. The control account is also the main point for authorizing, managing, and measuring the work, such as where planned value, earned value, and actual cost are determined; therefore, a control account manager is assigned to each control account and responsible for the completion of work within their account.

b. Planning, Scheduling, and Budgeting

During the planning phase, several steps need to be taken, such as scheduling work, identifying products and milestones, establishing a performance measurement baseline, budgeting by cost elements, determining discrete work and objective measures, summarizing detail budgets for control accounts, creating different levels of effort planning and control, establishing overhead budgets, identifying management reserves, and reconciling to the target cost goal.

It is important to integrate the master schedule (IMS), which is the logical sequence of all authorized works and also includes all key milestones, events, and decision points. Production projects typically use Manufacturing/Enterprise Resource Planning (M/ERP) to produce the schedule. Milestones are important to enable the measurement of work accomplished, while the Performance Measurement Baseline is the representative of the planned scope for all authorized work that the project manager uses to assess project performance. It is a cumulative time-phased budgeted cost for the work schedule.

The budget for cost elements is typically about the same as the budget for all authorized work. These budgets will be assigned to each of the control accounts and be responsible for them. Discrete work has a relationship with the objective that is wanted by the project. This point related to budget and the use of resources compared to the duration of the project that the control account needs to manage, resulting in meaningful management-oriented events for performance measurement. Then, the budgets for all control accounts will be summarized to create the project budget. This control account budget will also serve as the limit for each activity and work package that will be controlled.

Level of effort related to the activity that is impracticable and applies only a little in terms of visibility to the actual performance, thus needs to be minimized. Management reserves and undistributed budgets are related to the risks and opportunities; therefore, a budget and management reserve account need to be planned for unplanned activity within the scope. The last aspect of planning, scheduling, and budgeting is reconciliation of target cost goals. The project baseline usually reflects the common agreement between the two parties involved, thus precluding unauthorized changes to the performance baseline.

Therefore, reconciliation to target cost needs to be done by also adding management reserves instead of only internal program budgets.

c. Accounting Consideration

These steps play a role during the project execution phase. Several activities have been suggested to be done by the ANSI/EIA-748 EVM guidance. The activities include recording direct costs, summarizing direct costs by the WBS elements, summarizing direct costs by the OBS elements, recording and allocating indirect costs, identifying unit and lot costs, and tracking material costs and quantities.

This guide is closely related to the reporting style that is conducted regularly by the project contractor or client. Recording direct costs is a really important aspect of project monitoring. This helps to ensure that the actual costs collected can be directly compared to the associated budgets for that work. The reporting style needs to be in the same language and format as the general book account (accounting system). This cost collection needs to cover the cost report at the level of WBS as well as OBS elements.

Beside the direct cost, reports on the allocation also need to include the indirect cost, which also needs to be included in the accounting system. Therefore, the management can easily access the document and control the indirect cost. Unit and lot costs are related to the equivalent units or lot costs budgeted, ensuring the accounting system produces actual unit or lot costs for measuring cost performance. The last aspect of accounting attributes is tracking and reporting material costs and quantities. This aspect is also important, especially in relation to the comparison between the planned material costs for completed work and the actual material costs. This comparison provides actual and important information about the earned value of the project if it is related to the cost, and it can also create visible cost deviations if there is one implied.

d. Analysis and Management Reports

This activity also occurred during the project execution phase. The activities in this chapter are related to the information and data collected regularly and then processed to get the earned value under control. Some of the analysis that needs to be done in the report, such as schedule, cost, and other significant variances, indirect cost variances, summarized performance data and variances, implementation of corrective actions, and estimates at completion,

Schedule and cost variances are the differences between the planned budget and the actual budget for the same work. The project manager should evaluate these variances to determine the effects of the deviations from the performance baseline so that the project manager can then decide how to handle these changes. The project manager needs to give full attention to the significant variances that will create big changes in terms of the project baseline, especially if the variances happen in the critical path, which will impact the project schedule. Beside the direct cost variances, indirect cost variances also need to be reported because they are related to the project budget. In the reporting phase, all of those variances need to be summarized to provide a clear understanding of the project conditions. They also identify the problem areas coming from all levels of organization and project scope.

After the problems and changes have been detected, the project manager can apply corrective actions to bring the project back to plan or mitigate the impacts that may be caused by these changes. On the other hand, estimates at completion can be predicted to ensure the continued visibility of the cost, schedule, risks, and opportunities, as well as the resources and materials for the remaining works.

e. Revisions and Data Maintenance

The last few steps of applying a standard EVM are related to the execution and finishing phases of the project. The activities include incorporating change in a timely manner, maintaining baselines and reconciling budgets, controlling retroactive changes, preventing unauthorized revisions, and documenting performance measurement baseline changes.

Incorporating changes related to incorporating work scope for authorized changes into the performance measurement baseline change in a documented and timely manner, if necessary, allows a new scope to be executed. This change will also be related to the change in budget; therefore, the project manager needs to reconcile the current budget prior to the change in contract value. Retroactive change is related to adjustments in change caused by rate changes and economic price adjustments. This change should be limited to the budget that affected work scope budgets.

Appendix C. NDIA Guideline for Scaling EVMS

	ITEMS	ANSI/EIA-748 GUIDELINE	SCALABILITY ASPECT
1. Organizing for Project Management			
	1.1 Establishing the Project Organization	2. Define the Project Organization (OBS)	Can be scaled by limiting the number of levels and size of the project organization.
	1.2 Defining the Authorized Work	1. Define Work Scope (WBS)	Based on size (number of levels), type of project, and complexity of the scope, the number of control accounts
	1.3 Assigning Organizational Responsibility for Work	5. Integrate WBS/OBS to Create Control Accounts	Responsibility Assignment Matrix (RAM) size and detail
	1.4 Integrating EVMS Processes	3. Integrate Processes	Logical level of integration level of detail in deciding estimation, planning, scheduling, work authorization, and cost accumulation
2. Establishing and Maintaining an Integrated Project Schedule			
	2.1 Identifying Schedule Content and Requirements	6. Schedule the Work	Scalability in the type of project. The schedule should be detailed enough so the critical paths can be determined for the project's entire period of performance. The control accounts (level of WBS and OBS) establish the basic framework of the schedules. Small projects should contain the expected sequence of work, significant interdependencies between segments of work, and time phasing of authorized measurable work at a level of detail
	2.2 Integrating Schedules with the WBS and OBS	6. Schedule the Work	On small project, the need for detail level integration may be satisfied at the control account level for those efforts deemed to have the highest risk for success
	2.3 Structuring Schedules for Progress Statusing and Forecasting	7. Identify Products/Milestones for Progress Assessment	Understand the driver in determining project milestone which are the number and level of the control accounts. Scalability can be done by constructing the schedule to include the least number of milestones needed to objectively measure progress. Small projects with low risk could be scaled by using longer or larger work packages and planning packages with fewer interim milestones, and the percent complete could be used as the primary EV measurement technique. Using the terms of 0/100 and 50/50 can be done in a simple project
	2.4 Maintaining Baseline and Forecast Schedules	23. Identify Significant Variances for Analysis	Small projects should focus specific detail planning on near-term efforts and maintain future work in larger, scheduled packages for management flexibility. The focus is on limiting the amount of detail information in the schedule which is required for the day-to-day management of the effort.
3. Defining Budgets and Authorizing Work			
	3.1 Authorizing Work Scope and Budget for Resources	9. Authorize and Budget by Cost Elements	Small projects should have a work authorization process at the control account level with budgets planned by elements of cost, using varying degrees of formal documentation. If a WBS is developed for a small project, it could be a work authorization document by including information such as charge numbers, period, manager responsible, and budget
	3.2 Planning Resource Budgets for Control Accounts	10. Determine Discrete Work and Objective Measures	Scaling could be accomplished by allocating control account budgets to work packages represented in the IMS by using either a weighted milestone or percent complete EV technique.
	3.3 Planning Resource Budgets for Future Effort	8. Establish the Performance Measurement Baseline	Small projects should create a near-term planning window based on project milestone definitions, within which detailed control accounts and work packages are created.
	3.4 Confirming Accurate Budget Distribution	11. Sum Detail Budgets to Control Account	The establishment of the control account and summary level planning packages in the organizing process. Each control account must summarize properly to the authorized amount or the total value of the project will not reconcile with the value authorized by the customer.
	3.5 Establishing Objective Measures of Work Progress	7. Identify Products/Milestones for Progress Assessment	Small or low risk projects could use longer duration or larger dollar value work packages or control accounts; for travel or material, a single control account could be used, a high level WBS element or charge code could be used for all travel or material, EV performance could be taken as travel occurs or material is purchased, LOE could be used as the EV measurement
	3.6 Planning Resource Budgets for Non-Measurable Effort	12. Level of Effort Planning and Control	The number of LOE tasks in a small project should be held to a minimum, ensuring most tasks are being identified. Scalability could be achieved by placing all LOE scope within one or a few work packages
	3.7 Creating Holding Accounts for Work Scope and Budget	14. Identify Management Reserve and Undistributed Budget	Small project's management reserve should be commensurate with the level of risks and opportunities identified by the project manager. Undistributed budget may not apply when the work scope is easily identified to all the control accounts
	3.8 Maintaining Control of the Performance Measurement Baseline	32. Document PMB Changes; Reconcile to Target Costs	All changes to the project baseline must be documented in accordance with the project's change control process; small project change control process may incorporate less formal documentation
4. Interfacing the EVMS with the Accounting System			
	4.1 Ensuring Actual Costs are Comparable to Project Budgets	16. Record Direct Costs	Small project should collect and report actual direct costs at control account level. In the absence of a formal accounting system, a financial spreadsheet could be used to accumulate hours, work in progress, invoices, travel and material costs, and other expenses.
	4.2 Establishing a Cost Collection Structure to Support Management Requirements	17. Summarize Direct Costs by WBS elements; 18. Summarize Direct Costs by OBS Elements	The direct costs in control account must summarize into only one higher level WBS and OBS element. Consider summarizing the costs from the accounting system to the control account level before importing the data into the EVMS.
	4.3 Collecting Actual Unit/Lot Cost for Deliverable Items	20. Identify Unit and Lot Costs	This guideline does not apply for a small project in a non-manufacturing environment. When it is, a small project should capable to isolate unit costs. Using spreadsheet and should be able to differentiate between completed units and work-in-progress

5. Managing Using Project Performance Information			
	5.1 Providing Performance and Cost Variances for Project Analysis	22. Calculate Schedule Variance and Cost Variance	Revising thresholds for a small project and by establishing external and internal variance analysis requirements that are at different WBS level based on high cost, schedule drivers, or project risk. Focusing on cumulative variances only and focusing on only the most important variances.
	5.2 Analysing Significant Variances	23. Identify Significant Variances for Analysis	Revising variance thresholds for a small project; Establishing external and internal variance threshold at different WBS level based on the top cost and schedule drivers or risk factors; Generating and reporting on cumulative variances only; Analysing only the most important variances not driven by the variance threshold; Increasing the dollar value/percentage; Using both dollar value and percentage; Using looser threshold during execution and tighter threshold at completion; Setting the dollar threshold for a control account as a variable based on one month's worth of work for that control account
	5.3 Preparing Summarized Information for Management Evaluations	25. Summarize Performance Data and Variances for Management	Small project can focus on summarized information at the project level for analysis and corrective action implementation. As the project size increases, the level of management attention should also increases and will also require intermediate managers to evaluate the impact of variances on portions of the project as well as coordinate corrective actions.
	5.4 Determining and Implementing Appropriate Corrective Action	26. Implement Corrective Actions	Identification of corrective actions at the previously established control account or intermediate levels
	5.5 Evaluating and Updating Estimates of Project Costs	27. Maintain Estimate at Completion	Produce EAC on a regular basis for the remaining work at or below the control account level, the estimates should be summarized up through the WBS and OBS to the project level for management visibility and control. Scaling through limiting the depth and breadth of the WBS which reduces the number of control accounts requiring EAC updates. Reducing the frequent of developing EAC i.e. quarterly at the control account level. Limiting the amount of required supporting documentation
6. Incorporating Approved Changes into the Project			
	6.1 Making Changes to Project Plans and Budget	28. Incorporate Changes in a Timely Manner; 29. Maintain Baseline and Reconcile Budgets	Small project use of informal documentation, such as financial spreadsheet or other electronic media to capture changes to scope, schedule, and budget is still acceptable. Reducing or streamlining the number and level of approvals required on baseline change documentation can also facilitate timely approval and change incorporation into the PMB.
	6.2 Maintaining Correlation for Approved Project Values	30. Control Retroactive Changes	All changes must be traceable to the original baseline. In small project, change control can be simplified by using a single document, which include contract budget base, performance measurement baseline, management reserve, undistributed budget, and estimate at completion
	6.3 Establishing Procedures for PMB in Excess of Authorized Project Value	31. Prevent Unauthorized Changes	Small project not necessarily execute formal replanning, in the condition of OTB/OTS applied, small projects could limit the impact of the process on the project by evaluating resource needs at a high WBS level, based on lower-level inputs for establishing the new plan
7. Managing Project Material Items			
	7.1 Identifying all Material Items Required to Execute the SOW	1. Define Work Scope (WBS)	Scalability dependent on the WBS that was prepared in process 1. Review of the work scope of the lowest WBS level should reveal the types and quantities of materials needed.
	7.2 Scheduling Material Requirements	6. Schedule the Work	Acquire all needed material items early in the project and maintain them in a dedicated storage area. This approach should only be taken when material requirements are firmly established
	7.3 Establishing Budget Values for Material Items	10. Determine Discrete Work and Objective Measures	Material work package may be established within the same control account as the labour work packages that will consume the material
	7.4 Ensuring Accounting System Interface Supports Project Management Needs	21. Track and Report Material Costs and Quantities	Small project could use a financial spreadsheet that is separate from the accounting system, with costs recorded at point of receipt (acceptance), point of stock (inventory) point of issue to work-in-progress (consumption) and taking consideration residual or scrap inventory. The high value/critical material should be planned and tracked with greater rigor. Scaling can also be done by planning and tracking low value/non-critical material in a single control account
	7.5 Providing Performance and Cost Variances for Project Analysis	23. Identify Significant Variances for Analysis	Revising the variance threshold for a small project; Establishing external and internal variance threshold at different WBS levels based on the top cost and schedule risk factors; Generating and reporting on cumulative variances only; Analysing only the most important variances not driven by the variance threshold
	7.6 Determining and Implementing Appropriate Corrective Action	26. Implement Corrective Actions	Identification of corrective actions at the previously established control account or intermediate levels
	7.7 Evaluating and Updating Estimates of Project Costs for Material	27. Maintain Estimate at Completion	Produce EAC on a regular basis for the remaining work at or below the control account level, the estimates should be summarized up through the WBS and OBS to the project level for management visibility and control. Scaling through limiting the depth and breadth of the WBS which reduces the number of control accounts requiring EAC updates. Reducing the frequent of developing EAC i.e. quarterly at the control account level. Limiting the amount of required supporting documentation
8. Managing Subcontracted Work Effort			
	8.1 Identifying all subcontract items required to execute the SOW	1. Define Work Scope (WBS)	After decision for subcontract for project requirement and distinction between major and minor subcontractors is made, subcontractor EV information required can be limited by limiting the size or extension of the subcontractor WBS against which reporting will be required

	8.2 Establish Subcontract Management Organization	2. Define the Project Organization (OBS)	Scaling through establishing a single individual or team to manage all subcontracted efforts within the project. The person or team must have technical skills and understand the support for the progress represented by the subcontractors BCWP
	8.3 Scheduling Subcontractor Requirements	6. Schedule the Work	All elements and the level of detail of the schedule should be agreed upon by the supplier and customer. Limiting the WBS and OBS levels and their intersections reduces the lines of detail required in the schedule. For subcontracted work effort, the project schedule should contain the expected sequence of work, significant interdependencies between segments of work, and time-phasing of authorized measurable work at a level of detail which reflects the risk of the effort being managed
	8.4 Establishing Subcontract Budget Values	9. Authorize and Budget by Cost Elements	Scalability options are minimal. Tracking the subcontractor profit fees in separate work packages would facilitate the analysis of subcontractor by allowing the managers to focus on cost performance
	8.5 Ensuring Accounting System Interface Supports Project Management Needs	16. Record Direct Costs	small project should collect and report actual direct costs at the control account level by WBS or OBS. A financial spreadsheet could be used to accumulate hours, work in progress, invoices, travel and material or subcontractor costs, and other expenses.
	8.6 Providing Performance and Cost Variances for Project Analysis	23. Identify Significant Variances for Analysis	Revising the variance thresholds for small project; establishing external and internal variance thresholds at different WBS level based on the top cost and schedule driver or risk factors; Generating and reporting on cumulative variances only; analysing only the most important variances not driven by the variance thresholds
	8.7 Determining and Implementing Appropriate Corrective Actions	26. Implement Corrective Actions	Identification of corrective actions at the previously established control account or intermediate levels
	8.8 Evaluating and Updating Estimates of Project Costs for Subcontracts	27. Maintain Estimate at Completion (EAC)	The project level analysis of the submitted EAC can be conducted at the subcontract level using technical knowledge of the subcontract progress and performance measurement metrics
9. Managing Indirect Budgets and Costs			
	9.1 Identifying Functional Responsibility for Indirect Management	4. Identify Overhead Management	Manager to control indirect costs. The process should be documented. Small project in controlling indirect costs can be assigned to a single person
	9.2 Ensuring Proper Allocation of Indirect Budgets in the PMB	19. Record/Allocated Indirect Costs	Small project's indirect budget should be established in accordance with the project's direct budget, using an allocation method consistent with the manner in which actual indirect costs will subsequently be applied to the project
	9.3 Providing Appropriate Allocation of Indirect Costs to Projects	19. Record/Allocated Indirect Costs	in small project, the amount of indirect rates can become an agreement from the customer and supplier for the duration of the project; use of financial spreadsheet can be used to generate all indirect costs on a monthly basis followed by year-end reconciliation to recognize adjustments in applied overheads
	9.4 Providing Analysis of Indirect Performance to Projects	24. Analyse Indirect Cost Variances	when the cost collection system of a small project segregates direct and indirect costs, indirect cost analysis should be conducted and reported in a consistent manner.

Appendix D. ABCD Project Classification Questionnaire

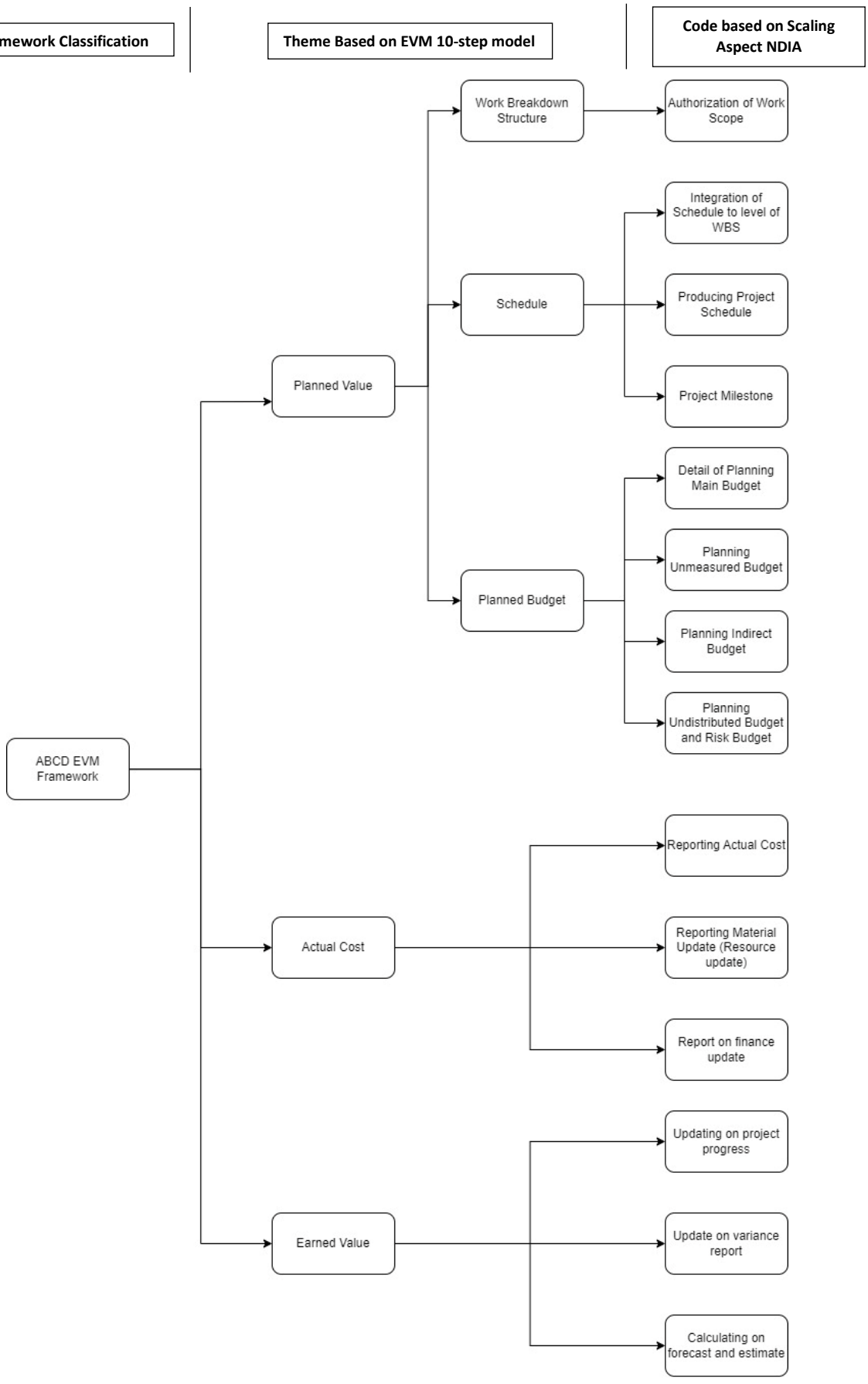
Question	Answer options
1. Financial exposure	
1.1 What is the maximum estimated contract liability that Van Oord is exposed to?	1. < €25 million
	2. € 25 - 100 million
	3. € 100 - 250 million
	4. > € 250 million
1.2 What is the estimated Van Oord share of the total contract value?	1. < €150 million
	2. => € 150 million
1.3 In what form does Van Oord participate in the project (joint venture)?	1. Independent/non-integrated
	2. Integrated Joint Venture
1.4 What is the likelihood of late or non-payment by the Client to Van Oord?	1. Very limited by nature of Client (e.g. western governments, oil majors).
	2. Existing risk but limited due to mitigation measures taken. Potential payment risk is mitigated by the Client providing payment guarantees or VO obtaining credit risk insurance.
	3. Existing risk not and/or not fully mitigated and/or extended payment term involved. Potential payment risks are not (sufficiently) mitigated by the Client provided payment guarantees or VO obtaining credit risk insurance.
2. Contract form	
2.1 What is the form of contract with Van Oord's Client?	1. Charter (e.g. BIMCO)
	2. Framework Agreement
	3. Construct, Engineer Construct, Transport and Installation or Van Oord contract conditions (e.g. FIDIC Blue Book, FIDIC Red Book, UAV, RAW)
	4. (Plan) Design and Construct, Engineering Procurement Construction (and Installation) or Innovation Partnership (e.g. FIDIC Yellow Book, UAV GC(I), NEC, ICE)
	5. Design Build Maintain (and Operate) or Availability guarantee
3. Supply chain	
3.1 What is the share of the 3rd party scope within the Van Oord share?	1. < 25%
	2. 25 – 50%
	3. > 50%
3.2 What is the hard coverage ratio of the 3rd party share?	1. >90%
	2. 50%-90%

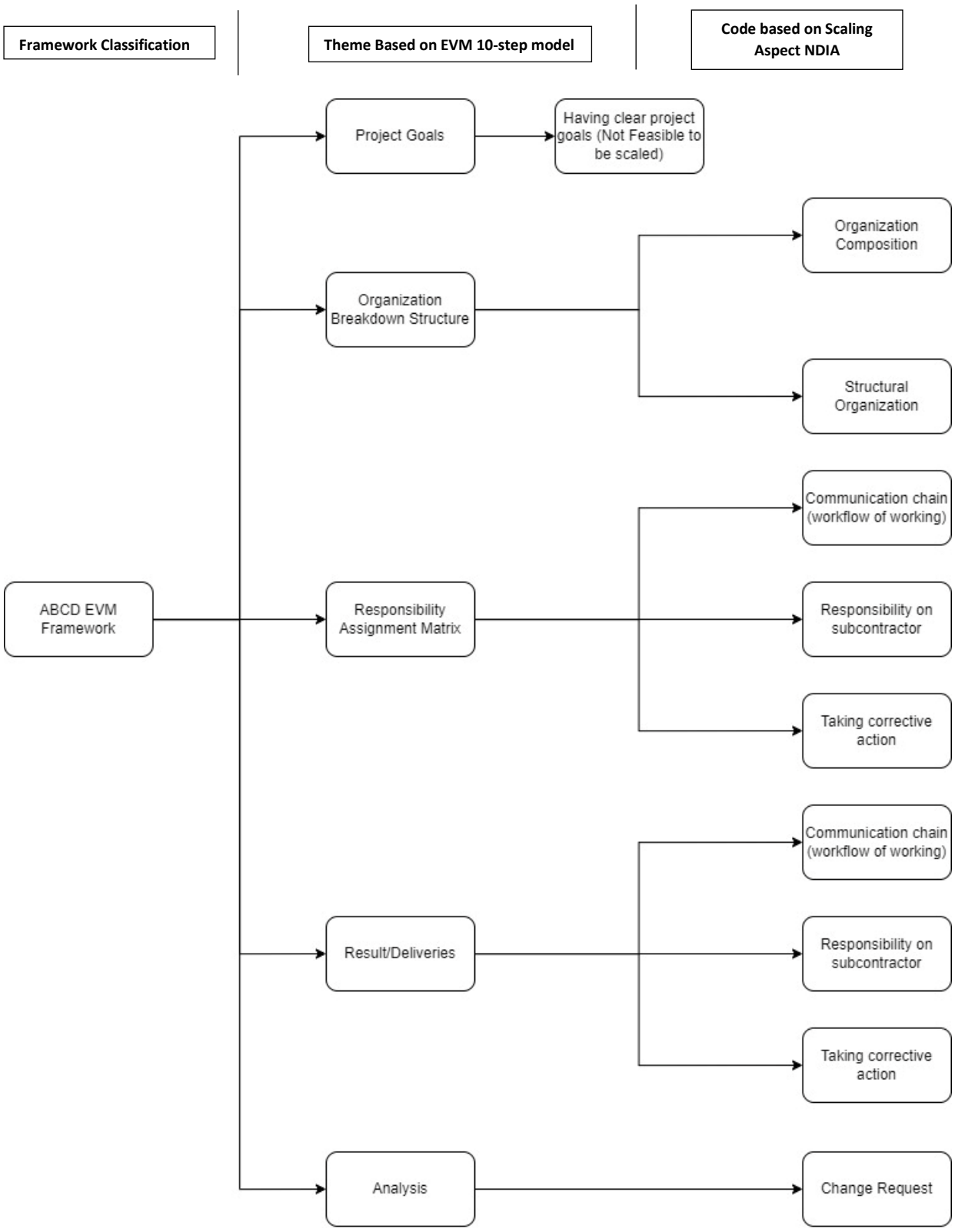
Question	Answer options
	3. < 50%
4. First time	
4.1 Has Van Oord and/or a key partner executed a project at the proposed location in the last 10 years?	1. Yes
	2. No
4.2 Has Van Oord and/or a key partner successfully executed all main scope components and planned techniques in the last 10 years?	1. Yes
	2. No
4.3 Does Van Oord require new or need to retrofit mission critical equipment to execute the project?	1. No
	2. Yes
5. Site Conditions	
5.1 Who retains the soil risk?	1. The Client retains the soil risk and/or the soil risk is conditioned.
	2. Van Oord retains the soil risk.
5.2 Is the available soil information sufficient and reliable?	1. Information on soil conditions on site is according to expectation and of sufficient quality (e.g. accurate, consistent, amount, reliable).
	2. Information on soil conditions on site is according to expectation however quality is questionable.
	3. Information on soil conditions on site is unknown or adverse.
5.3 Who retains the adverse weather risk?	1. The Client retains the adverse weather risk and/or the adverse weather risk is conditioned.
	2. Van Oord retains the adverse weather risk.
5.4 Is the available metocean data sufficient and reliable?	1. Information on metocean conditions on site is according to expectation (characteristics and the bandwidth, i.e. standard deviation) and of sufficient quality (e.g. accurate, consistent, amount, reliable).
	2. Information on metocean conditions on site is according to expectation (characteristics and the bandwidth, i.e. standard deviation) however quality (e.g. accurate, consistent, amount, reliable) is questionable.
	3. Information on metocean conditions on site is unknown, adverse and/or the bandwidth i.e. standard deviation is too large.
6. Relationships & Resources	
6.1 How is Van Oord's relationship with the Client?	1. Good relationship with Client, no issues expected or known to be cooperative.
	2. Normal relationship with Client, no positive or negative experience.

Question	Answer options
	3. Limited relationship with Client or changes in key contacts.
	4. Difficult relationship with Client and requires a lot of attention or Van Oord has not worked for this Client in the last 10 years.
6.2 How is Van Oord's relationship with the key subcontractor(s)?	1. Good relationship with key subcontractor(s), no issues expected or known to be cooperative.
	2. Normal relationship with key subcontractor(s), no positive or negative experience.
	3. Limited relationship with key subcontractor(s) or changes in key contacts.
	4. Difficult relationship with key subcontractor(s) and requires a lot of attention.
6.3 Are interface issues expected with other stakeholders (not being Client and subcontractors) or stakeholders with significant influence?	1. Good behaviour expected from other stakeholders, no issues expected or limited influence.
	2. Normal behaviour with other stakeholder, limited issues expected and no significant influence.
	3. Challenging behaviour from other stakeholders could occur, but influence is limited.
	4. Significant influence expected from other stakeholders and requires dedicated effort from management.
6.4 What is the country risk according to the Atradius Country Risk Map?	1. Low risk (i.e. Atradius score 0-2)
	2.Moderate-Low Risk or Moderate Risk (i.e. Atradius score 3-4)
	3. Moderate-High Risk (i.e. Atradius score 5)
	4.High Risk or Very-High Risk (i.e. Atradius score 6-7)
6.5 What is the outcome of the Environmental, Social & Governance due diligence process?	1. A completely positive result from the First Assessment and/or no red flag(s) from the Standard Assessment.
	2. Enhanced Assessment was required, and the outcome is that all risks are mitigated within the project activities.
	3. Enhanced Assessment was required, and the outcome is that there are risk(s) which cannot be or are difficult to be mitigated within the project activities. An ESG working group is established,
6.6 Do we have the right main equipment available?	1. No equipment is required to execute the main scope components.
	2. All main scope components can be executed with Van Oord equipment which is available according to the Corporate Equipment Planning (CEP).
	3. All main scope components can be executed with Van Oord equipment which is available according to the Corporate Equipment Planning (CEP).

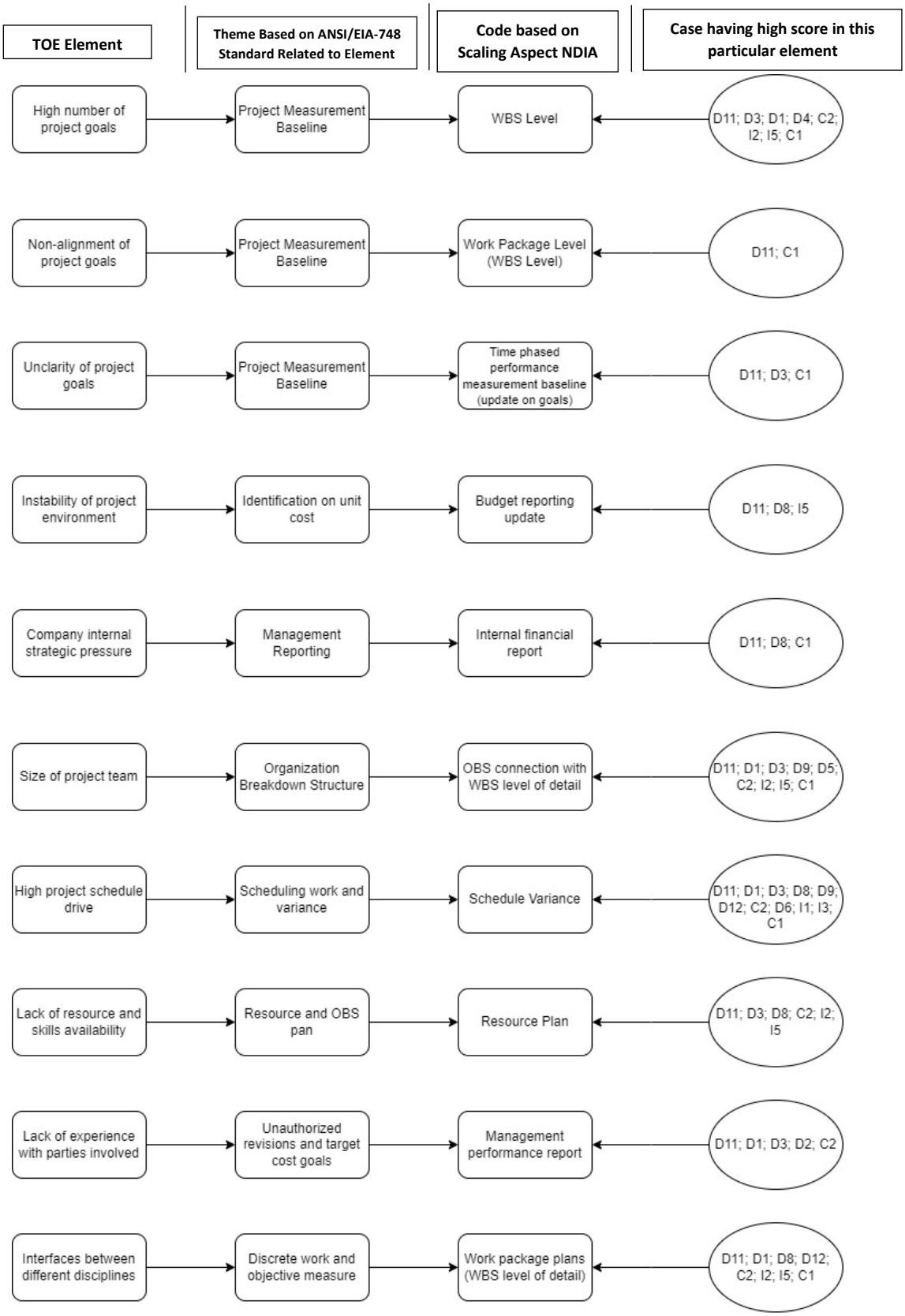
Question	Answer options
	4. Partially main scope components can be executed with Van Oord equipment which is available according to the Corporate Equipment Planning (CEP) and partially it will be executed with external equipment because we either don't have the right equipment or it is unavailable according to the CEP.
	5. All main scope components need to be executed with external equipment because we either don't have the right equipment or it is not available according to the Corporate Equipment Planning (CEP).
6.7 Do we have the right people available to execute the project?	1. It is most likely that all required qualified staff with sufficient capacity is available within Van Oord.
	2. It is uncertain that all required qualified staff with sufficient capacity is available within Van Oord, however what Van Oord is missing is certainly sufficiently available in the labour market.
	3. It is uncertain if all required qualified staff with sufficient capacity is available within Van Oord or in the labour market.
	4. It is highly uncertain that all required qualified staff with sufficient capacity is available within Van Oord or in the labour market.
7. Special risks	
7.1 Does this project have extraordinary special risks or deviations from the golden rules which are not already covered elsewhere in this questionnaire?	1. No
	2. Yes there is a special risk with a potential major impact on project level. To be further specified.
	3. Yes there is a special risk with a potential major impact on BU and/or corporate level. To be further specified.
8. Recovery possibilities	
8.1 Does the project planning or execution method provide possibilities to recover and meet the contractually imposed milestone(s)?	1. For all main scope components recovery options can be applied to secure the anticipated result.
	2. For some of the main scope components recovery options can be applied. For other components a first-time right is critical to secure the anticipated result.
	3. For all main scope components a first-time right is critical to secure the anticipated result.
8.2 What is the bleed out time during peak of execution until the project result is gone?	1. >12 weeks of unforeseen delay before project result is gone.
	2. 4-12 weeks of unforeseen delay before project result is gone.
	3. <4 weeks of unforeseen delay before project result is gone.
8.3 What is the bleed out time during peak of execution until the project gross margin is gone?	1. >24 weeks of unforeseen delay before project gross margin is gone.
	2. 8-24 weeks of unforeseen delay before project gross margin is gone.
	3. <8 weeks of unforeseen delay before project gross margin is gone.

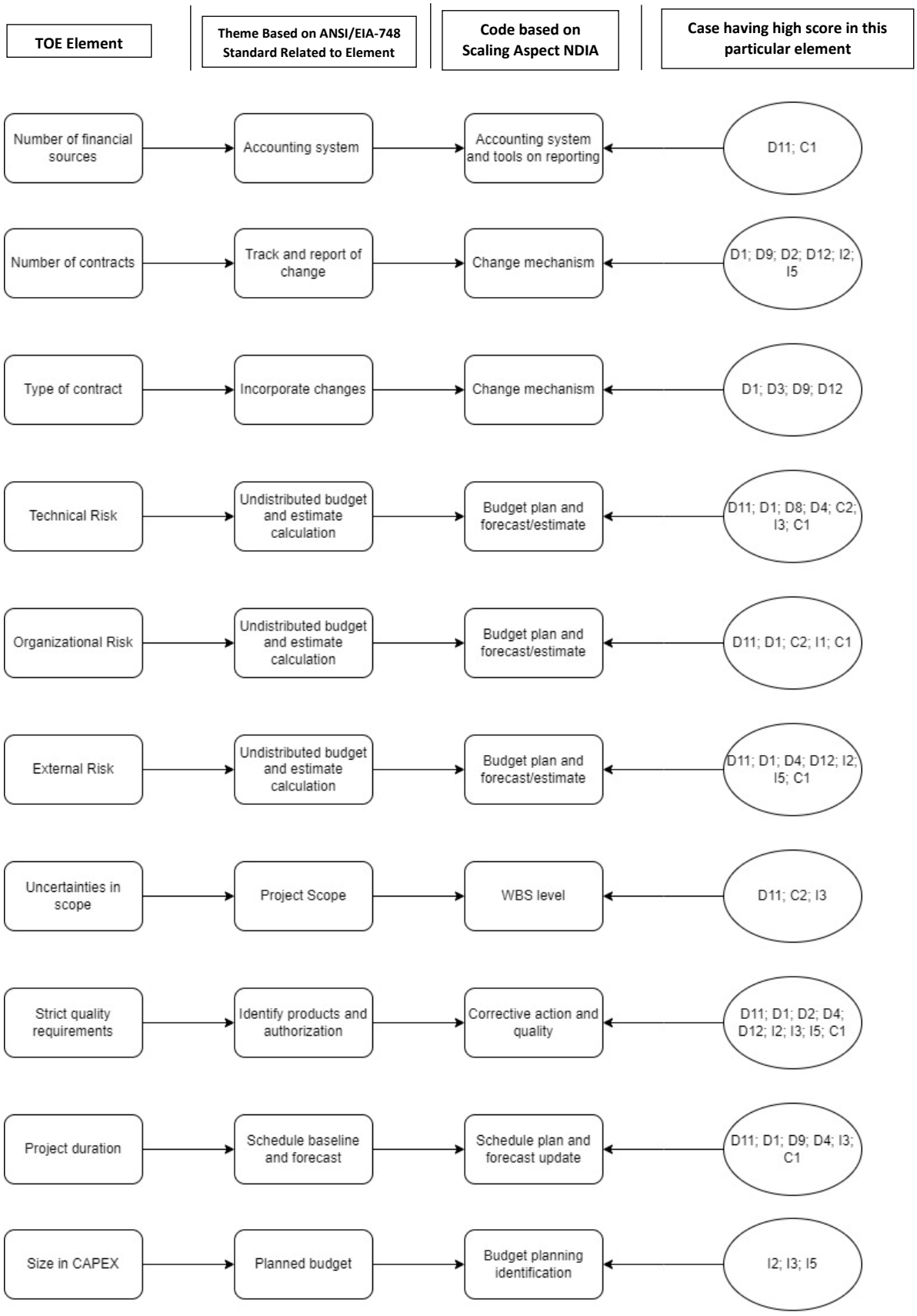
Appendix E. Code Diagram for ABCD EVM Framework

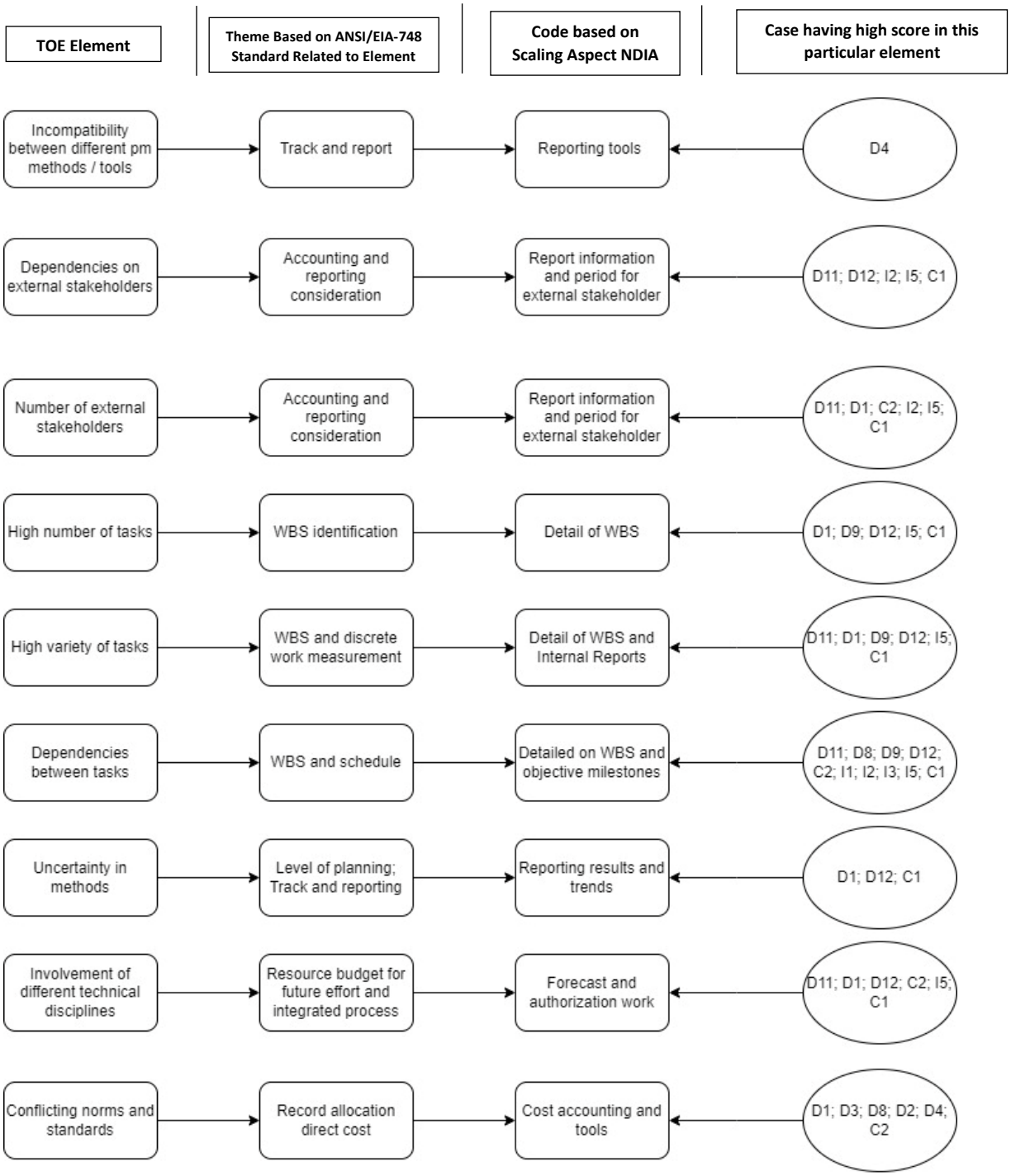



Framework Classification
Theme Based on EVM 10-step model
Code based on Scaling Aspect NDIA
ABCD EVM Framework
Project Goals
Having clear project goals (Not Feasible to be scaled)
Organization Breakdown Structure
Organization Composition
Structural Organization
Responsibility Assignment Matrix
Communication chain (workflow of working)
Responsibility on subcontractor
Taking corrective action
Result/Deliveries
Communication chain (workflow of working)
Responsibility on subcontractor
Taking corrective action
Analysis
Change Request

Appendix F. Code Diagram for TOE EVM Framework




TOE Element
Theme Based on ANSI/EIA-748 Standard Related to Element
Code based on Scaling Aspect NDIA
Case having high score in this particular element
Number of financial sources
Accounting system
Accounting system and tools on reporting
D11; C1
Number of contracts
Track and report of change
Change mechanism
D1; D9; D2; D12; I2; I5
Type of contract
Incorporate changes
Change mechanism
D1; D3; D9; D12
Technical Risk
Undistributed budget and estimate calculation
Budget plan and forecast/estimate
D11; D1; D8; D4; C2; I3; C1
Organizational Risk
Undistributed budget and estimate calculation
Budget plan and forecast/estimate
D11; D1; C2; I1; C1
External Risk
Undistributed budget and estimate calculation
Budget plan and forecast/estimate
D11; D1; D4; D12; I2; I5; C1
Uncertainties in scope
Project Scope
WBS level
D11; C2; I3
Strict quality requirements
Identify products and authorization
Corrective action and quality
D11; D1; D2; D4; D12; I2; I3; I5; C1
Project duration
Schedule baseline and forecast
Schedule plan and forecast update
D11; D1; D9; D4; I3; C1
Size in CAPEX
Planned budget
Budget planning identification
I2; I3; I5


TOE Element
Theme Based on ANSI/EIA-748 Standard Related to Element
Code based on Scaling Aspect NDIA
Case having high score in this particular element
Incompatibility between different pm methods / tools
Track and report
Reporting tools
D4
Dependencies on external stakeholders
Accounting and reporting consideration
Report information and period for external stakeholder
D11; D12; I2; I5; C1
Number of external stakeholders
Accounting and reporting consideration
Report information and period for external stakeholder
D11; D1; C2; I2; I5; C1
High number of tasks
WBS identification
Detail of WBS
D1; D9; D12; I5; C1
High variety of tasks
WBS and discrete work measurement
Detail of WBS and Internal Reports
D11; D1; D9; D12; I5; C1
Dependencies between tasks
WBS and schedule
Detailed on WBS and objective milestones
D11; D8; D9; D12; C2; I1; I2; I3; I5; C1
Uncertainty in methods
Level of planning; Track and reporting
Reporting results and trends
D1; D12; C1
Involvement of different technical disciplines
Resource budget for future effort and integrated process
Forecast and authorization work
D11; D1; D12; C2; I5; C1
Conflicting norms and standards
Record allocation direct cost
Cost accounting and tools
D1; D3; D8; D2; D4; C2

Appendix G. TOE Score for Project Case

TOE Aspect	Project List																
	D11	D1	C1	D3	D8	D9	D2	D5	D7	D4	D12	C2	D6	I1	I2	I3	I5
High number of project goals	5	4	5	4	2	2	2	1	1	4	3	5	2	2	4	3	5
Non−alignment of project goals	5	3	5	3	1	2	2	0	1	3	3	2	1	1	2	1	2
Unclarity of project goals	4	2	4	4	1	2	1	1	1	1	2	2	1	2	2	1	2
Instability of project environment	4	3	3	2	4	2	1	1	1	2	2	2	1	3	2	1	4
Company internal strategic pressure	4	2	4	2	4	1	3	1	1	1	3	2	2	3	2	3	2
Size of project team	4	4	4	4	2	4	2	4	1	3	3	5	2	3	4	3	5
High project schedule drive	5	4	5	4	4	4	3	2	1	3	4	5	4	4	3	4	3
Lack of Resource & Skills availability	4	3	3	5	4	3	3	2	3	1	3	4	1	3	4	3	4
Lack of Experience with parties involved	4	4	3	5	3	3	4	1	3	2	3	5	2	3	2	3	1
Interfaces between different disciplines	5	4	5	3	4	3	2	1	1	3	5	5	1	2	4	2	5
Number of financial sources	5	2	5	2	1	1	1	1	1	1	1	2	1	1	1	2	1
Number of contracts	3	5	3	2	2	4	4	1	2	1	4	3	2	3	5	3	5
Type of contract	3	4	3	4	3	4	2	1	1	1	5	2	1	3	3	3	3
Technical risks	5	5	4	3	5	3	3	2	1	4	2	4	2	2	3	4	3
Organizational risks	4	4	4	2	2	3	2	2	2	2	3	5	2	4	2	3	2
External risks	4	4	4	3	2	2	2	2	2	4	4	3	3	3	4	3	4
Uncertainties in scope	4	3	3	3	2	3	3	2	1	2	3	5	1	3	1	4	2
Strict quality requirements	5	5	5	2	1	2	4	1	1	5	5	1	3	2	4	5	5
Project duration	4	5	4	2	1	4	3	3	1	4	3	2	3	1	3	4	3
Size in CAPEX	3	1	3	0	1	3	3	1	1	1	2	2	2	2	4	4	5
Incompatibility between different pm methods / tools	3	1	3	2	0	1	3	1	1	4	3	0	1	1	1	1	1
Dependencies on external stakeholders	4	3	4	3	2	1	2	1	2	3	5	3	3	2	5	1	5

TOE Aspect	Project List																
	D11	D1	C1	D3	D8	D9	D2	D5	D7	D4	D12	C2	D6	I1	I2	I3	I5
Number of external stakeholders	4	4	4	2	1	1	3	2	2	3	3	4	3	2	4	3	5
High number of tasks	3	5	4	2	2	4	2	1	1	1	5	3	3	2	3	2	5
High variety of tasks	5	5	5	3	3	4	1	1	1	1	5	2	2	2	3	3	5
Dependencies between tasks	4	2	4	2	4	4	1	1	1	1	5	5	1	4	5	5	5
Uncertainty in methods	3	4	5	3	3	3	2	1	1	2	4	1	1	1	2	3	2
Involvement of different technical disciplines	4	5	5	3	2	3	2	1	1	2	5	4	3	2	3	3	4
Conflicting norms and standards	3	4	3	4	4	2	4	1	1	4	1	4	2	3	1	2	1

Appendix H. Project Used as Case for High TOE Element Score

TOE Aspect	HIGH Complex EVM (4-5)
High number of project goals	D11; D3; D1; D4; C2; I2; I5; C1
Non−alignment of project goals	D11; C1
Unclarity of project goals	D11; D3; C1
Instability of project environment	D11; D8; I5
Company internal strategic pressure	D11; D8; C1
Size of project team	D11; D1; D3; D9; D5; C2; I2; I5; C1
High project schedule drive	D11; D1; D3; D8; D9; D12; C2; D6; I1; I3; C1
Lack of Resource & Skills availability	D11; D3; D8; C2; I2; I5
Lack of Experience with parties involved	D11; D1; D3; D2; C2
Interfaces between different disciplines	D11; D1; D8; D12; C2; I2; I5; C1
Number of financial sources	D11; C1
Number of contracts	D1; D9; D2; D12; I2; I5
Type of contract	D1; D3; D9; D12
Technical risks	D11; D1; D8; D4; C2; I3; C1
Organizational risks	D11; D1; C2; I1; C1
External risks	D11; D1; D4; D12; I2; I5; C1
Uncertainties in scope	D11; C2; I3
Strict quality requirements	D11; D1; D2; D4; D12; I2; I3; I5; C1
Project duration	D11; D1; D9; D4; I3; C1
Size in CAPEX	I2; I3; I5
Incompatibility between different pm methods / tools	D4
Dependencies on external stakeholders	D11; D12; I2; I5; C1
Number of external stakeholders	D11; D1; C2; I2; I5; C1
High number of tasks	D1; D9; D12; I5; C1
High variety of tasks	D11; D1; D9; D12; I5; C1
Dependencies between tasks	D11; D8; D9; D12; C2; I1; I2; I3; I5; C1
Uncertainty in methods	D1; D12; C1
Involvement of different technical disciplines	D11; D1; D12; C2; I5; C1
Conflicting norms and standards	D1; D3; D8; D2; D4; C2

Appendix I. Interview Quotes for ABCD EVM Framework

1. Authorization of Work Scope – Scaling WBS

Project D: Setting the standard following the guideline since it is not applicable

"Next question about WBS, because you already mentioned you familiar with it and are you using it towards the project (D5) you mentioned? And to which level?"

"The first one was not applicable" – D5 (Respondent S2)

Project C: WBS Level 3 based on Figure 8 similar to Planning Package or Work Package level

"Yes, that's correct. And for the (D3), you might not, we end up with Level 3. So then we purely had the faces we had the different packages within the face" – D3 (Respondent P2)

"It's a good question. I know in (D2) it was through a very detailed level because the client requested it, the Level 3." – D2 (Respondent M2)

"No, no, I think if I have to translate it in that way. We probably in (I1). We only use levels, maybe two or three levels maximum" – I1 (Respondent D1)

Project B: As mentioned not to have a complicated WBS level and preferably to have a simpler WBS.

"We want to have the work break breakdown structure, but also to keep it simple and in our view the advice that we got from the people was to make it. Too complicated, too complicated. Yeah." – C2 (Respondent S2) on commenting the received WBS condition on the project is too complicated and detailed.

Project A: WBS developed until the level of work and sub work packages activities

"I think for the the the two projects I was been working on, I think the WBS, I don't know exactly amount of levels with quite a number of details. For example, taking the (D11) project again. Then we had a work package system. Where I think you had about 20 out your main work packages and then of course you detail this out and till to sub work packages and these sub work package included in also comprised again of work package activities" . – D11 (Respondent P1)

2. Integrated Schedule – Method on defining project schedule

Project D: Schedule baseline following the tender contract and creating clear sequence

"Where the your basis is the planning from the tender. Yeah, that is your starting point…. Tender with a different vessel. So you need to update it if you get a new vessel with a new productivity. That the cubic meters doesn't change, so your activity duration will change. That's what you have to update or you have sometimes different point of view on sequence of the activities" – D5 (Respondent S2)

"Yeah, usually that is based on the on the estimate and basing yourself on what you think you can do" – D7 (Respondent C3)

Project C: Assumption and Judgement also needed for validating schedule plan also having analysis on critical equipment.

"Yeah. Tenders and tenders estimating department look at previous projects and they say, OK, we worked in this location before. We've used the special before, so we know what kind of cycle times or estimates for production we should be using and then we take that" – I2 (Respondent C2) (Responend asked if assumption is involved on the project)

"We have a planner that uses Primavera to make a schedule including a critical path. And we use that to plan our vessel costs. So it's I look at a vessel, any one vessel and say yeah, stock mobilization, stock operations and operations, weather delays, statistical then I know my costs will run from here to here" – I2 (Respondent C2)

"they have to come together in the tender phase is what we call the cycle sheets. So we analyze the cycle of a critical piece of equipment." – I1 (Respondent D1)

Project B: Specific planner on site to monitor schedule change

"We have a planner that uses Primavera to make a schedule including a critical path. And we use that to plan our vessel costs. So it's I look at a vessel, any one vessel and say yeah, stock mobilization, stock operations and operations, weather delays, statistical then I know my costs will run from here to here and at those days and like I said in the beginning time is money for that duration" – I5 (Respondent C2)

"The Planner is updating. Of course the progress. But to me, it's really let's say towards the client" – D6 (Respondent C1)

Project A: Including subcontractor and people analysis, instead of unmeasured duration, probabilistic calculation being conducted to understand the production rates

"There's two things to get a project, you first make an estimate, so you make a a calculation. With the durations. That is the basis of your schedule. That is your input and one of the input parameters is the net production time. And that comes from the production estimate. Of course, it Is more flexible. Is the preparation time, mobilization time, set up time." – D1 (Respondent M1)

"Depending on the project type, we use quantities, so cubic metre of concrete, tonnes of steel, so the the (C1) project for example we had loaded the schedule also with concrete volumes and sheet pile. So the weight of sheet pile. Probably have been working on by that wasmuch earlier in the Petro chemical industry, we also loaded resources like people (subcontractor). And of course, if you want to and for example after that project, let's take the concreting works. We try to use, we call it norms. I don't know what the English words, but it's like the production rates, right? So for example if you do. If you have a. Heavy wall. It's 350 kilos of rebar. Each cubic meters, which of course has a different speed of building than if you have light. So if you have only 120 kilos per ton of a cubic meter of, that gives a different speed, how much you can do in a certain time frame. We all even do probabilistic analysis on that, which is much more sophisticated, and there I think we have a much better understanding on how much time something used on the production rates" – D11 & C1 (Respondent P1)

3. Integration of Schedule to WBS : Following the WBS level of detail.

4. Setting Project Milestone

Project D: Milestone following what been set by client

"That I had the milestones on the project that I've been on were client issued. OK. So you cannot change them." – D5 (Respondent S2)

Project C: Having interim milestone to be reported monthly

"OK, so very often you find that the the client has set. 90% of the milestones. Maybe you add from some yourself, but in in in (I1) we had a big list of milestones. I interim a key dates we had to meet." – I1 (Respondent D1)

"You know monthly we have a payment application to the client. So we claim to the client each time we achieve a milestone and again I use my DPR as my daily progress reports to see how many cables are installed, how many foundations are installed, etcetera." – I2 (Respondent C2)

"Just start counting from that milestone milestone on the contract. You actually have more time so there quite easy to interpret the contract in their favor, so if we make a schedule that is more stringent than theirs" – D2 (Respondent M2)

Project B:

"Of course you make your own planning. Yeah, based on on certain things and and the planning is then your your deadline so. And and the planning is of course based on on the end date as set by the by the client but but usually with the client you only have one date is when you have to complete the full project and and sometimes it can happen that you have intermediate deadline as well." – I3 (Respondent C3) (Respondent being asked about internal team target and methodology to create internal milestone)

"You know monthly we have a payment application to the client. So we claim to the client each time we achieve a milestone and again I use my DPR as my daily progress reports to see how many cables are installed, how many foundations are installed, etcetera." – I5 (Respondent C2)

Project A: Interim shorter milestone (weekly)

"Big milestones or in construction. I know for example, when I was doing the (D11) project we had. A twice a week, we had a construction meeting with also subcontractors to see what's going on" – D11 (Respondent P1)

5. Planning Budget: Detail on planning budget including all important aspect (mentioned by all project levels) following the level of WBS.

Project D: Semi-detailed unit cost

"that is also how it is offered then to the client and if accepted, the contract is based on those. Yeah, on those agreements and what you then do is is basically you rebuild a little bit the estimate based on how you as a project controller can manage or you can monitor your your expenditures. So what we usually do is you split it into mobilization costs, operational cost, and demobilization costs and then you have some some general staff on your project that you would like to monitor and you have some markup cost which is for example a risk budget. Your general overhead which are which is also charged" – D7 (Respondent C3)

Project C: Force detailed take-off estimation (on several aspect), balancing act and lump-sum on certain aspect.

"So we normally hatch foreign currency. We don't want to run the risk. It's not our business. So when we get paid in a certain currency, we just hatchet that we get a fixed rate. We put it in it and we don't run the risk." – I1 (Respondent D1)

"One is own equipment and the other one is for instance, third party equipment and 3rd party equipment can be done via a higher rate or it can be done via lump sum" – D3 (Respondent P2)

Project B: Force detailed take-off estimation (on several aspect)

"OK. But that that is basically the same with the the planning. Yeah, you get another piece of equipment. So you have to adjust also your work budget because another ship has a different cost. So that has to change" – C2 (Respondent S2) (Adjustment on uncertain aspect of estimation)

Project A: Detailed take-off estimation

"Yeah, it's of course the also here it depends a bit on the type of work for example if it's engineering of course look at the amount of man hours but also the rate of the people and indeed also price inflation." – D11 (Respondent P1)

6. Non-measurable and future effort budget: deciding how each project calculating non-measurable budget.

Project D: Creating percentage on budget

"Usually it's on the overall budget, so you base it on, on your turnover for example, and then to go turnover is, yeah, in a certain percentage you take as inflation or or risk budget." – D7 (Respondent C3)

Project C: Using percentage with the rule of balancing act. So, if the unmeasured budget exceeding the prepared percentage budget, then change can still be done under the concept of balancing act.

"In the end it it is a percentage, yes, yeah" – I1 (Respondent D1) (respondent asked about unpredictive budget)

"Yeah, but that is then always the balancing act in the tender phase, you still have options to maneuver." – I1 (Respondent D1) -> The concept of balancing act refers to change on budget can be done as long as it is still under the planned budget (for unmeasured cost).

Project B: Calculation including tax and currency planning

"Obviously, operations drive our costs and our revenues, but with good tax planning, you can save a lot of money as well or bad tax spending. You lose a lot of money. So things like import. Taxes currency exchanges. If you don't do your hedges or your stops correctly, you lose a lot of money on fluctuating oil prices or currency rate exchange rates." – I5 (Respondent C2)

Project A:

"The (C1) project for example, we tried to look ahead. We had of course our cost contingency because you never know how prices will develop in five years time because these these project long run a long time, you have a cost contingency for that. What I'm used to do is normally you do to the you take the budget. OK, as a sort of fixed" – C1 (Respondent P1)

7. Indirect Budget Plan: how each project level calculating indirect budget plan

Project D: Having fixed indirect rate cost

"Usually in the estimate we have a separate line. This this indirect cost thing has something with inflation. Then you include the costs of course on the on the lines where they where they where, where you incur them and then you deduct. Something from the inflation budget." – D7 (Respondent C3)

Project C: Indirect cost added as percentage to budget summary

"So the percentage of indirect cost is a lot smaller. Yeah, bonds, taxes, insurances, tax with. If you look only at finance bonds." – I1 (Respondent D1)

"…And where the indirect cost, which could be insurance of the project, it is the project staff. That accommodation of the project and the project staff, etcetera, insurance taxes, profit. The head office needs to be paid as well, so that's then added on top of the direct cost." – D2 (Respondent M2)

Project B: Indirect cost added by percentage per activity

"Per activities, yeah. So I know to to fabricate the the monopiles was a subcontractor the subcontractor for so many tonnes of steel, that mamamama, etcetera, etcetera. And yeah, productivity." – I5 (Respondent C2) (Respondent asked about indirect cost)

Project A: Calculating integrated calculation for indirect cost

"At the acquisition phase, you calculate the estimated cost. And you always go for also the profit. You go for the risk items, you cover your markups and you try to have all the costs which are there which you can face are included" – D1 (Respondent M1) (Respondent asked about indirect cost)

"Yeah, we have a very complicated estimating tool. Well, it's not a complicated tool itself, it's it's just excel. We're shifting from excel to A to a software package, but in the end, at the moment it's still excel based estimate" – D9 (Respondent M2)

8. Management Reserve and Undistributed Budget: Setting budget and measurement of risk possibilities

Project D: Management reserve not really applicable, only additional risk budget included in the unmeasured budget

"In (D5), it was not that much applicable" – D5 (Respondent S2) (Respondent asked about measuring project risk)

Project C: Project Manager responsible for risk change and risk budget

"So you have a budget and the project controller tail tells the project manager OK and this time we have spent so much. So I don't as project manager have to worry about it. I get that information as a project manager." – I1 (Respondent D1)

"Yeah, depends a lot indeed on on on what happens. So if it's usually the project manager is involved." – D2 (Respondent M2)

Project B: Involvement of Risk Manager

"We had really somebody working on on risk. So there was a a risk manager involved in the project and. She really make together with different people from the project team. She sits together with them, identifies the risks." – I3 (Respondent C3)

"Are we able to improve or let's say was this the easy part of the execution of the project and then we go into a more complicated part, so it's always a joint effort. But for instance. The involvement of the planner of the risk engineer the involvement, let's say, of the cost estimator. Who who made all the assumptions. Yeah, that's that's, that's not happening. It's not 1 integrated thing. That's also one of the, let's say, the the aims we're looking at that we want to make it an integrated team who is working on it." – D6 (Respondent C1) – wish of having risk engineer on board

Project A: Review by project management Team and Risk Manager

"So you identify possible risks. You identify also opportunities and and that's is then transferred from the tender team to the project team. And then the project teams reassess the the risk register" – D9 (Respondent M2) – Risk assessed by team

"However, there's always also. QHC manager Which reviews the measures and the QHC manager is discussing it with the project manager." – D1 (Respondent M1)

9. Cost incurred for executing work on a project: Detailed aspect on reporting activities following the level of WBS, however for higher level, there are some additional activity can be done.

Project D: Level on recording cost following the WBS level of detail. In this level may using simple estimated actual.

"We don't work with percentage of completion. Then on a monthly basis, you simply check. I've dredged xxxx cubic metres." D7 (Respondent C3)

Project C: Level on recording cost following the WBS level, having survey team to report achievement

"Yeah, someone's doing installation. Someone's doing cables. One guy's doing survey. One guy's doing design" – I2 & I5 (Respondent C2)

"Well, methodology is mainly in terms of. Well, to to monitor the progress of the works, it's survey. So to express it all the work being done in in volumes of material which we shift from place A to B or install in the works" – D2 (Respondent M2)

Project B: Level on recording cost following the WBS level, having survey team to report achievement

"Yeah, someone's doing installation. Someone's doing cables. One guy's doing survey. One guy's doing design" – I2 & I5 (Respondent C2)

"So we didn't measure earned value in that respect, OK, we we had to execute this channel. You know it should be this wide and this deep. So you have your survey data and based. On that you update your progress to the client" – D6 (Respondent C1)

Project A: Level on recording cost following the WBS level, survey team and using integrated system

"…another also a weekly progress meeting and. then in the Triangle Operation Survey engineering. I think we had adhoc meetings.." – D9 (Respondent M2)

"So that's that's our survey department. It's really helpful with that cost monitoring" – D9 (Respondent M2)

"We had SAP, yeah, but that was for financial management. But it was more like a where everything was stored" – D11 (Respondent P1)

10. Accounting system for updating material used: How to record actual update on material and what information should be updated

Project D: Using simple financial spreadsheet to monitor and highlighted critical important material.

"In this case it's all Excel, so there's not really, really a difference." *– D7 (Respondent C3)*

"The tool in in (D5) that was actually from my preceded over there was very simple in Excel that he had set it up" – D5 (Respondent S2)

Project C: Use extensive system of monitoring material and focus can be limited to critical important material

"From the BCR, there are all kinds of views and dashboards made, which is good, fine, but there are tools to for the company to see how we're doing and for me and the BCR is level I need to monitor." – I1 (Respondent D1) – Using Budget Cost Report to monitor material use and movement in budget

"We have daily progress reports from the vessels which we use. We have ad hoc reports which tell us the cycle times and that we use an app within the Van Oord currently. Yeah, if you. So I use that as well. Offered to see what the cycle times are, but mostly The Daily Progress reports I use. I get my information from the consumptions cycle." – I2 (Respondent C2) – having specific daily reporting

"Yes also, especially if it's for instance rock, which. Needs to be delivered. Let's say we have a weekly delivery rate. So then we really need to monitor whether we get the amount of work that we need. So that is. Monitored in Excel, usually by the procurement officer or could also be the Superintendent or a logistics officer, then you get your load bills"- D2 (Respondent M2) – having delivery rate to monitor material, load bills

"OK. Depends what you want to monitor. OK, the tool is related to what you want to monitor. If you want to monitor fuel consumption. Then you need the tool for fuel consumption. If you want to monitor your progress, you need the tool for progress. If you want to monitor your financial situation. You need to monitor your financial situation. If you want to monitor your risk. You do risk register." – D8 (Respondent M1) – specified tools

Project B: Use extensive tools and focus on all material value

"OK, so that is that is going into really a lot more detail and and obviously with a bigger project you have more steps in the project. So the the whole build up of the Excel file is more extensive. When you have a bigger project so. Let's say that with the bigger projects I have, yeah, maybe 1000 lines in Excel that I use" – I3 (Respondent C3) – extensive tools to report and update material as whole

"We have clear visibility, but other purchases now we are have let's say no bill, no pays or introduce something, no commitments, no invoices. We pay it without an underlaying and it's also from the last. Years in the past we didn't have. Often what we did is locally set something up for the local purchases, but the purchases from the head office you didn't have, let's say, full insights. On the project. But now with the No PO, no pay, that's that's better available" – D6 (Respondent C1) – application of No PO No Pay regulation towards all material purchase

Project A: Using a more extensive system to monitor update on change, procurement, and material.

"We had SAP, yeah, but that was for financial management. But it was more like a where everything was stored, if you will. All right, so. We used a database system where we could see what was ongoing, how much invoices we were signing off and these kind of things. We had a tool where you indeed monitor progress" – D11 (Respondent P1)

"So then we really need to monitor whether we get the amount of work that we need. So that is monitored in Excel, usually by the procurement officer or the could also be the Superintendent who is or or a logistics officer" – D9 (Respondent M2)

11. Update on financial condition: Period on updating financial condition

Project D: Quarter update on finance condition

"That's why we have the three monthly financial the quarterly financial reporting where you can adjust any changes to the tax regulations or supplier rate increase or inflation that you can adjust it" – D5 (Respondent S2).

"The real meetings with between the project manager and and somebody sitting in the business unit, yeah, those are only taking place on a quarterly basis" – D7 (Respondent C3)

Project C: Monthly update on financial condition

"the finance person does it. Monthly, together with the project manager, we say what's happened this month and then we report the big changes. Even then, monthly is enough ….. in the monthly, yeah, no, it's just financial, financial and cash flow depends" – I2 (Respondent C2)

"Once a month, you officially need to give the figures because that is out of the banks out of the guarantees that has been given, but also out of the bonds that are given for the project. You need to officially submit by a finance officer your financial report." – D3 (Respondent P2)

Project B: Having monthly financial update

"I think there are some things in in progress of that you can actually increase the interval of using the report to to rather than financial reporting every three months. Very detailed if we change it. You will be able to do that on a monthly basis" – C2 (Respondent S2) – Suggestion on having financial update monthly

"in the monthly, yeah, no, it's just financial, financial and cash flow depends, it depends one is results accounting results and one is cash flow" – I5 (Respondent C2)

Project A: Having weekly budget cost report

"you can translate that with the weekly cost to get an idea. Of earned value. However, it's not, yeah. It's not incorporated in the financial reporting" – D1 (Respondent M1) – having weekly period update on finance update

12. Quantification of worth the work to date: How to update on achievement

Project D: Using percentage to measure Earned Value

"It depends a little bit on the the type of project that you run because we usually work with percentage of completion method…" – D7 (Respondent C3) (Respondent asked about methodology to translate progress into earned value)

Project C: Implementation of extensive Earned value such as using S curve to monitor differences

"It's very extensive the the BCR, the PQR. Sorry, it's very extensive. It is also the S curve. It is the state of the finance. How much money have we spent, how much money have we got from the client." – I1 (Respondent D1)

"If you make a more elaborate progress report so that in that we also focus entire project, we can complete plans progress of the project. So we focus of the. Planning, which is accompanied by S-curve or other histograms or relevant information" – D4 (Respondent S1)

Project B: Implementation of extensive Earned Value using Daily Progress Report to monitor milestone

"You know monthly we have a payment application to the client. So we claim to the client each time we achieve a milestone and again I use my DPR as my daily progress reports to see how many cables are installed, how many foundations are installed, etcetera, etcetera. So that's the milestones upstream and downstream. We look at what of the subcontractor supplied, have they supplied, how many sets are supplied, how many sets are are, are shipped, how many sets are coated and all these, yeah, we have very many milestones in a project to determine both upstream to the client and downstream to the subcontractors, how they can claim money from us and how we can claim money from the client." – I5 (Respondent C2)

Project A: S curve setting also giving project condition and update it daily

"I would like to get the curve just a S curve or a or a histogram or something like that with with the brief explanation that says much more than of steps and of course, I'd like to see green, orange, red kind of traffic light … I regularly my regular pros reportings monthly, but you see of course that teams have sometimes daily meetings, especially if they're big milestones or in construction." – D11 & C1 (Respondent P1)

13. Reporting Variance: How often does the variance should be monitored

Project D: Monthly basis and doing simple comparison

"Yeah, that's also on a monthly basis. So every every period that we receive an update, we always compare against previous update and against the estimate. So the original budget." – D7 (Respondent C3) (Respondent asked about variances)

Project C: Variance calculated based on value, generating cumulative variance, included on the monthly report

"Monthly I do that." – I1 (Respondent D1) (Respondent asked about frequency on calculating variances)

"There's 2 comparisons, one to budget and one through define what happened in the past month" – I2 & I5 (Respondent C2)

"You do every month you look at your variances. Are you making an indication of your variances with an update outlook of the end of project result" – D8 & D1 (Respondent M1)

Project B: Variance calculated based on value, generating cumulative variance, included on the monthly report

"There's 2 comparisons, one to budget and one through define what happened in the past month" – I2 & I5 (Respondent C2)

"Yeah, January, February. If everything runs the way it should, we leave it as it is and then in March we start scrutinizing it again and then suddenly you do it monthly. The same mechanism then you do it more more often." D6 (Respondent C1)

Project A: Variance calculated monthly focusing on critical value

"Monthly for variances, so what you do every month you look at your variances. Are you making an indication of your variances with an update outlook of the end of project result" D8 & D1 (Respondent M1)

"it should be of course, every month and of course some so like scheduled performance SPI I'm doing that every month, yeah… But I think if you're looking at cost performance index, yeah, it is done, but not in the way, at least for value management how it should be done" – D11 & C1 (Respondent P1) – specific mentioning to be focus on critical value using indexes (SPI and CPI) or value analysis

14. Forecast: How often does the forecast should be estimated

Project D: Monthly on monitoring forecast, level should be following the WBS level of detail

"Yeah, that was in preparation phase. So with the client, it was monthly, monthly with my client, with my colleague. It was continuously basically." – D5 (Respondent S2) (Respondent asked about methodology to monitor forecast)

"Like I did that on a monthly basis. And and we actually do that for all the projects on a monthly basis." – D7 (Respondent C3)

Project C: Monthly update on forecast and estimate at completion following the WBS level of detail

"Then we went to one month. So every month we reset the clock. OK, what have we achieved? What is outstanding and? The advances by normally during a project, you know what your running costs are" – I1 (Respondent D1)

"In the monthly report, you give a clear insight over what you what your position was at the beginning of the month. You give your position by the end of the month and you also give a clear forecast so that the higher management is informed in what you are facing in the upcoming period." – D3 (Respondent P2)

"The end of the month and you also give a clear forecast so that the higher management is informed in what you are facing in the upcoming period" – D2 (Respondent M2)

Project B: Monthly update on forecast and estimate at completion following the WBS level of detail

"Like I did that on a monthly basis. And and we actually do that for all the projects on a monthly basis" – I3 (Respondent C3) (Respondent asked on how often does they monitor forecast)

"Yeah, to be honest, I calculated quarterly. I should do it monthly" – D6 (Respondent C1) – Recommendation on doing forecast monthly

Project A:

"Yes, every week we we have to report it" – D9 (Respondent M2) (Respondent asked on how they monitor and calculate forecast)

15. Organization Composition: Whom should involve on the project site/project team

Project D: Involving small team

"You mean people, peoples, etc. (D5) was like 5-6 people." – D5 (Respondent S2)

"So for example, the the project in Angola and the Namiba project was really small and. And there we actually only had the project manager going to site at some point in time when the operations started" – D7 (Respondent C3)

Project C: Having team member on location at least until superintendent/work package manager level

"you have the offshore construction manager who has a clear role and he has superintendents with him and she and a survey and whatever he needs project. So it's more to be like an organization which handling the technical aspects" – I1 (Respondent D1)

"Still have to coordinate the travel. But I don't have a travel coordinator on site that will be done by the Superintendent. So what you see is the smaller the project. the more diversified are the tasks of a person in a team." D8 (Respondent M1) – suggestion on having also superintendent level on site

Project B: Having team member on location at least until work package manager level

"So in that respect, I would say, yeah, we were rather thin in project controlling a lot of people in execution, project manager. It's a works manager and superintendents, surveyors." – D6 (Respondent C1)

"We had a whole team of surveyors and there was well, like I said, the risk manager. There were several works managers involved as well. So, yeah, then you really, you really talk about a team of how much was it? I think at least 15 or 20 people. Dedicated full time to that project for the whole duration of the project" – I3 (Respondent C3)

Project A: Detailed organization level and including subcontractor in the organization

"And we did some initial, we were teamed up with the developer. Yeah, we had a concession." – D1 (respondent M1) – Clear structure with other parties

"the bigger the project, the bigger the project team should be. In (D1), I have 500 people on site…"- D1 (Respondent M1)

"that was all organized locally because in (D9), we have quite a big local organization. So yeah, those people are are employed on the on the local contracts. And they go from project to project. So they they are based locally." – D9 (Respondent M2) – Subcontractor or local worker included in the contract

16. Structural OBS: Whether the application of OBS is necessary or not

Project D: Not requiring structural OBS, following the condition of project team involved, OBS not necessarily to be created structurally.

"I've heard of it of the term, but not really applicable. we actually only had the project manager going to site" – D7 (Respondent C3) (Respondent asked about familiarity with WBS)

Project C: Having organization system to define organization.

"we have because all projects have organization charts and there are actually. They're often quite a link" – I1 (Respondent D1)

"So we don't let ourselves led by surprising we make it a very clear procedure so that everybody knows exactly what to do." – D3 (Respondent P2) – Organization defined so that each person have information about task

"We have specialists. Our organization chart, if that helps you give you some idea about how the process people that will give you some idea you know." – I2 (Respondent C2)

"You can look bottom up aside all these activities of all these yes activities, all these we put in in the breakdown structure in the work packages, all these work packages we put together and we group again and then we group how you do bottom up or you do top down" – D8 (Respondent M1)

Project B: Having Organization system to define organization

"Now we have, let's say organization chart of course we have. We have an OBS. That's what we have. We have a resource breakdown, absolutely. We have we have course types, we have activities and phases" – D6 (Respondent C1)

Project A: Correlation of OBS with the WBS

"I would like to recognize my own team in the WBS and I said I said of I say. Basically that shouldn't be the way you set up a WBS. It shouldn't be because that we organize it that the responsibilities." – D11 (Respondent P1)

17. Workflow of working: regarding communication chain

Project D: Simple report to project manager

"Over there, but it's pretty common also on other projects. Every morning 7:30 till 8. Just a small briefing. What are you going to do today? OK. What were any hassles yesterday? Especially from different departments" – D5 (Respondent S2) (Respondent asked about communication within team)

Project C: Having discussion with project manager (report)

"So you have a budget and the project controller tail tells the project manager OK and this time we have spent so much. So I don't as project manager have to worry about it. I get that information as a project manager." – I1 (Respondent D1)

"…the finance person does it. Monthly, together with the project manager, we say what's happened this month and then we report the big changes… if it has a big cost impact, he will discuss with the project manager." – I2 (Respondent C2) – Project Manager informed about the update through discussion

Project B: Project director or business unit involved and should be informed

"Well, the real meetings with between the project manager and and somebody sitting in the business unit, yeah, those are only taking place on a quarterly basis" – I3 (Respondent C3) – defining the involvement of business unit level

"it sometimes happens that when you even the project manager reports to the headquarters, the incident with the corrective measures" – C2 (Respondent S2)

Project A: Involvement of project director with proper mechanism

"The project management, so let's call it the the project director needs to sign off and you would like to also sign off. For example the. Contracts manager and the finance manager to make sure that we also follow the proper route that all the calls have been so. Has been have been investigated all. That we comply with the contract, that it also properly translated to contract language to avoid that change that hit you hit" – D11 (Respondent P1)

18. Handling Subcontractor: Who should be responsible for handling subcontractor

Project D: Not Applicable based on project case, solution following the minimum standard

Project C: Generally one manager assigned for handling subcontractor

"Very often you have divided your work in such a way that, for instance, that subcontract is 1 activity or and that's how you monitor that subcontract" – I1 (Respondent D1) – indicating subcontractor to be one activity

"Yeah. And somebody else's managing design. The reclamation and another from the design of the canal, because that is 1 sub design company who's designing everything. So you get a design manager with the design. Yeah, the way of living and the way of working for design that they have a certain language, design language and certain standards and. Yeah, they manage each other. If you look to procurement. The works manager." – D8 (Rspondent M1)

Project B: Package manager to handle subcontractor

"but also just meetings with the package managers. How are things going, which kind of cost you expect, which variational is do you have to your subcontractors, mostly just informal meetings and formal meetings within the project team, as our management…" – I5 (Respondent C2) – indicating that subcontractor controlled by package manager

Project A: Having procedure and team to handle subcontracting

"to have a successful subcontract, you need three elements. You need the scope. Which is with the works manager who's responsible for the content. Yeah, you need a good subcontract with the right incentives. And right conditions which is with the contracts manager. Are you need a good procurement process, so you need a procurement officer who who does the procurement process and these three elements." – D1 (Respondent M1)

"A twice a week, we had a construction meeting with also subcontractors to see what's going on. Are we on time? Because sometimes they're half a day delay might have an impact of of a month where, for example, the project I'm currently working on the two." – D11 (Respondent P1) – subcontractor included on the construction team

19. Handling Corrective Action: Who should be responsible to handle corrective action

Project D: Project Manager taking corrective action

"Yeah, that depends really. On the on on what the decision is that should be taken. Usually the way it works is that the project manager from a project is always is in responsible for that project" – D7 (Respondent C3)

Project C: Specific manager or package manager involved

"If you have it over just a contractual term. The procedures are there so that the specific manager can just follow the procedures and as long as he follows the procedure, he is always be allowed to do the decision himself." – D3 (Respondent P2)

"Yeah, it will be the package manager. Every scope of work. Yeah, as a package manager, yeah. In dredging, that would be like a works manager." – I2 (Respondent C2) (Respondent asked about who takes the decision of taking corrective action)

Project B: Project manager taking action with help from risk manager/division

"Yeah, yeah, no, it sometimes happens that when you even the project manager reports to the headquarters, the incident with the corrective measures. Yeah, taken or to be taken. That they had changed. With advice from the QHE department." – C2 (Respondent S2)

"Usually the way it works is that the project manager from a project is always is in responsible for that project" – I3 (Respondent C3)

Project A: Involvement of project director and regulate quality checker

"Yeah, so that depends very much on the change, but but if so, we talked about work packages and the responsibility for the work package, I think primarily the responsibility lies there. But of course, if the change has an impact on others then project management at the end of the day needs to. They do say, and my experience is for all the the project I work for normally. The project management, so let's call it the the project director needs to sign off and you would like to also sign off. For example the. Contracts manager and the finance manager to make sure that we also follow the proper route that all the calls have been so. Has been have been investigated all" – D11 (Respondent P1) – Involvement of Project Director

"For example, you need to measure the thickness or the height, yeah. And then if you can say, OK, this person who does that quality check" – C1 (Respondent P1)

20. Change of Performance Measurement Baseline: What are the thing that needs to be performed related to change and how often does it need to be conducted

Project D: Change decision requested by project manager and trend or update of project on weekly basis

"…in the end and the project manager takes all the decisions and and says yes or no. We we're not gonna do this preventive measure, but we're gonna do this…"- D5 (Respondent S2)

"How it works in the project like in in (D5) at a certain moment I started to do it also weekly more strict yet to be able to make notes because if you do it." – D5 (Respondent S2)

"What was it 3 or 4 weeks? Then automatically your the frequency of your meetings goes up, of course. But yeah, so in the end I think we had almost a weekly meeting, but that was just because the period of time was so short" – D7 (Respondent C3)

Project C: Having change procedure

"Yeah, those, that's those are the procedures. That I was talking about. So we don't let ourselves led by surprising we make it a very clear procedure so that everybody knows exactly what to do." – D3 (Respondent P2) (Respondent asked about change procedure)

"Yeah, as I said. So it starts with a if it's an instruction. So then like a a letter comes in with an instruction saying, well, this is please execute this and this kind of work. Then the first response would be that this is outside" – D2 (Respondent M2)

Project B: Having change management and procedure

"Yeah, we have the change management system, yeah."- C2 (Respondent S2)

Project A: Applying change procedure and variation register to keep tracking variation order

"The management of change procedure should be going and some of them are design developments which we say OK we chose to." – D11 (Respondent P1)

"…And so these are the variation orders. We we keep that, we keep track of that as well. In D9, we had a variation register. Executed a lot of work outside of the project.." – D9 (Respondent M2)

21. Preparing summarized information for management evaluation: how often does report should be reported to management and what are the information included

Project D: At minimum report about trends, safety, and lesson learned and reported quarterly with management

"…and on a quarterly basis, yeah, the the report is a bit more extensive. So you can really have a look at all the details, the different line items…" – D7 (Respondent C3)

"Schedule and time and cost updates or also have another update such as. Like incident, for example or environment conditions, incident, issues, pre-warning…" – D5 (Respondent S2)

Project C: Additional reporting outside the project progress, also report it quarterly

"We have safety measurements as well. Days since the last incident lost time incidents. How many incidents have caused us to lose time cases and needing medical attention. So there's safety measurements, there's quality measurements so. Number of non conformity reports and. There's. So there's lots of different reports which measure non financial things as well this CO2. So there's lots of different reports and non financial... There's formal communication, and there's informal communication. Formally, it's at a daily progress report CO2 report, a quarterly project report…." – I2 & I5 (Respondent C2)

"Yeah, project quarterly reporting and that's fairly extensive…. Now, quarterly project quarterly is very important." – I1 (Respondent D1)

Project B: Additional reporting outside the project progress and market update, also report it quarterly

"Like incident, for example or environment conditions and issues or problems solved." – C2 (Respondent C2) (Repondent asked about data received in the progress report)

"We have safety measurements as well. Days since the last incident lost time incidents. How many incidents have caused us to lose time cases and needing medical attention. So there's safety measurements, there's quality measurements so. Number of non conformity reports and. There's. So there's lots of different reports which measure non financial things as well this CO2. So there's lots of different reports and non financial... There's formal communication, and there's informal communication. Formally, it's at a daily progress report CO2 report, a quarterly project report…." – I2 & I5 (Respondent C2)

"…And then the report is discussed with let's say the Operations Department and the Finance Department for the head office and that happens, let's say every quarter" – D6 (Respondent C1)

"Yeah, choose a quote especially for the big packages. We will look around on the market. We have category managers who specialize in a certain something, yeah, so maybe fuel or maybe steel." – I5 (Respondent C2)

Project A: Additional of reporting market price change

"So inflation, especially the the last two years were of course inflation was. So yes, we we managed that but also price developments on steel sand, all these things are are men, shall we look at? Quantities we look at price. We look at subcontracts. I think we look at the whole scale."- D11 (Respondent P1)

22. Reporting subcontractor activity: Reporting subcontractor activity following the WBS level of detail

23. Baseline change request: procedure to monitor and report change

Project D: In the interview, not clearly mentioned in the interview about having log, however notes is suggested. Minimum activity following standard ANSI/EIA-748

"Not structured every morning in the daily system without making notes. You easily forget things discussed or actions" – D5 (Respondent S2)

Project C: Having dashboard to monitor change

"And I think there is already a step done quite recently, 3-4 years ago where we introduced this, what they call a dashboard" – I1 (Respondent D1)

"Yeah and you click it and it breaks it down and says sailing, checking, installing. Waiting on whether you can break it down like that and then you can see a cross section of all your activities and this is effectively what currently is. Similar to dashboard" – I2 & I5 (Respondent C2)

Project B: Having dashboard to monitor change and daily log

"Yeah and you click it and it breaks it down and says sailing, checking, installing. Waiting on whether you can break it down like that and then you can see a cross section of all your activities and this is effectively what currently is. Similar to dashboard" – I2 & I5 (Respondent C2)

"You report every month or you have like like daily logs and then so every month you like everyone on your team like updating whatever." – I5 (Respondent C2)

Project A: Application of variation register

"…And so these are the variation orders. We we keep that, we keep track of that as well. In D9, we had a variation register. Executed a lot of work outside of the project.." – D9 (Respondent M2)

Appendix J. Interview Quotes for TOE EVM Framework

1. High number of project goals – Establish and maintain a time-phased budget baseline – WBS detailed until the level of activity level

"I think for the the the two projects I was been working on, I think the WBS, I don't know exactly amount of levels with quite a number of details. For example, taking the (D11) project again. Then we had a work package system. Where I think you had about 20 out your main work packages and then of course you detail this out and till to sub work packages and these sub work package included in also comprised again of work package activities" . – D11 (Respondent P1)

2. Non-alignment of project goals – Following the WBS level of highest Complexity Level

"Yeah, we we are still establishing the rules, but basically, we would like to see an accountable person for a work package and you could assign responsibilities to various work packages or work package activities." – D11 & C1 (Respondent P1)

3. Unclarity of Project Goals – Update on project goals

"In the weekly management meeting, you're talking only about the the game Breakers, so then you say, OK, the budgets, the budgets for these and these and these ones are extended or are to less or overdue. So that everyone is aware of the amount of fire in the house. That is what you discussed on a weekly basis" – D3 (Respondent P2) – In discussing about game breakers and project condition to do it weekly

4. Instability of project environment – Identification of unit cost (planning contingency plan)

"Quarterly, we're reviewing the I would say risk contingency budget and I think that the probabilistic analysis on the schedule, because we did that as well for both parties" – D11 (Respondent P1)

"Obviously, operations drive our costs and and our revenues, but with good tax planning, you can save a lot of money as well or bad tax spending you lose a lot of money. So things like import taxes currency exchanges" – I5 (Respondent C2) -

5. Company internal strategic pressure – Internal management reporting

"But from a reporting point of view and a progress meeting measurement point of. Normally I would say I do a monthly reporting" – D11 (Respondent P1)

6. Size of project team – Detailing project team until the level of activity until activity level (WBS level 4) mentioned in most project case (D11; C2; I2; I5; D1)

"For example, taking the (D11) project again. Then we had a work package system. Where I think you had about 20 out your main work packages and then of course you detail this out and till to sub work packages and these sub work package included in also comprised again of work package activities." – D11 (Respondent P1)

"Now we go to the deepest level because we need to, like, get us to those various levels" – I2 & I5 (Respondent C2) (Respondent asked about WBS level)

7. High project schedule drive – creating project milestone and schedule variance (monthly) – mentioned in most project case (D11, D1, D8, D3. I1)

"Then I'm already on. Optimistic side, it should be of course, every month and of course some so like scheduled performance SPI I'm doing that every month, yeah" – D11 (Respondent P1)

"Monthly for variances, so what you do is in the three months you you take all the cost, all your exposures, everything you review, you look at it every on. On (D1), we did every month we did it, yeah" – D1 & D8 (Respondent M1)

"Monthly I do that" – I1 (Respondent D1) (Respondent asked about project variances)

8. Lack of resource and skills availability – Having clear work distinction and working on the same site to effectively shared information.

"They have of course scope of work where maybe a planner has a different view and the cost controller maybe even has a different view, and if they are really focus on their own discipline" – D11 (Respondent P1) – Having clear work distinction

"Yeah, it's very much very much. If someone had to say you can't be in the project team, which you have to sit at a different location because some projects do that, they say that operational team is on site. And the finance is support function should be in the head office. It won't work. There's so much informal communication at lunch at the coffee machine. Oh, yeah, walking around that you hear so much." – I2 & I5 (Respondent C2)

9. Lack of experience with party involved – Having regular meeting with external partner and doing activity logging

"And among that, more details on particular subjects or with the client or with the joint venture partner. Scheduled weekly meetings. So from daily to weekly" – C2 (Respondent S2)

"We are doing the activity logging so in at site we measure OK, the file is being picked up, we lift it and then we stop the clock" – D11 (Respondent P1)

"It will team of it externally or with subcontractors" – D1 (Respondent M1) (Respondent asked about information received on weekly meeting)

10. Interfaces between different disciplines – Detailing project level following WBS level

"For example, taking the (D11) project again. Then we had a work package system. Where I think you had about 20 out your main work packages and then of course you detail this out and till to sub work packages and these sub work package included in also comprised again of work package activities." – D11 (Respondent P1)

"Now we go to the deepest level because we need to, like, get us to those various levels" – I2 & I5 (Respondent C2) (Respondent asked about WBS level)

"We go quite high level, yeah. You do your breakdown. Let's say the the breakdown. Structure is quite high level, yeah" – D1 (Respondent M1)

11. Number of financial sources – Using tools as financial management (i.e. SAP); having financial specialist; and having database to monitor invoice

"We used a a database system where we could see what was ongoing, how much invoices we were signing off and these kind of things. We had a a tool where you indeed monitor your actual spendings…..We had SAP, yeah, but that was for financial management. But it was more like a where everything was stored…the SAP system is being set up by a financial guy or financial function, financial specialist" – D11 (Respondent P1)

12. Number of contract – quarter report on change and having variation register

"How much variation orders and extra claims do we expect to get? And what's the actual cost? Well, how many days in the vessel and what rate, et cetera, you know, yeah. So I do this every quarter in detail. By talking to other people." – I2 & I5 (Respondent C2)

"mostly every quarter, every quarter we do a complete budget control report or project quarter report and we forecast what the end of the project will look like from a revenue point of view" – I2 & I5 (Respondent C2)

"And so these are the variation orders. We we keep that, we keep track of that as well. In (D9), we had a variation register." – D9 (Respondent M2)

13. Type of contract – Application of change procedure

"Yeah, those, that's those are the procedures. That I was talking about. So we don't let ourselves led by surprising we make it a very clear procedure so that everybody knows exactly what to do." – D3 (Respondent P2) (Respondent asked about change procedure)

14. Technical Risks – Adding risk budget as percentage markup and monitor monthly

"Usually it's on the overall budget, so you base it on, on your turnover for example, and then to go turnover is, yeah, in a certain percentage you take as inflation or risk budget." – I3 (Respondent C3)

"You go for the risk items, you cover your markups and you try to have all the costs which are there which you can face are included." – D1 & D8 (Respondent M1)

"And every month you do the trends. Or very detailed project forecast depends a little bit or the trends. Have it make changes or a detailed report" – D1 (Respondent M1)

"Yeah, by having sufficient. So by having I would say monthly recessions depending a bit on the we can't have it on every team every month, which is a regular update of today's register" – D11 (Respondent P1)

15. Organizational Risks – Monthly update on forecast and markup by percentage on risk and unpredicted budget

"And every month you do the trends. Or very detailed project forecast depends a little bit or the trends. Have it make changes or a detailed report" – D1 (Respondent M1)

"Yeah, by having sufficient. So by having I would say monthly recessions depending a bit on the we can't have it on every team every month, which is a regular update of today's register" – D11 (Respondent P1)

"So a percentage of the project is given to the head office and that are indirect costs. Yeah, and you could contingency risk could also be indirect cost, but the examples you gave here salaries direct cost, yeah." – I1 (Respondent D1)

"You go for the risk items, you cover your markups and you try to have all the costs which are there which you can face are included." – D1 (Respondent M1)

16. External Risks – Monthly update on forecast and markup by percentage on risk and unpredicted budget

"We will look at our actual cost and then add at the bottom profit and risk and offer them the price." – I2 & I5 (Respondent C2)

"You go for the risk items, you cover your markups and you try to have all the costs which are there which you can face are included." – D1 (Respondent M1)

"And every month you do the trends. Or very detailed project forecast depends a little bit or the trends. Have it make changes or a detailed report" – D1 (Respondent M1)

"Every four weeks anyway" – I2 & I5 (Respondent C2) (respondent asked about frequency in calculating forecast)

17. Uncertainties in Scope – Detailing in scope and WBS

"I think for the the the two projects I was been working on, I think the WBS, I don't know exactly amount of levels with quite a number of details. For example, taking the (D11) project again. Then we had a work package system. Where I think you had about 20 out your main work packages and then of course you detail this out and till to sub work packages and these sub work package included in also comprised again of work package activities" . – D11 (Respondent P1)

18. Strict quality requirements – Specified person handling specified task

"For example, you need to measure the thickness or the height, yeah. And then if you can say, OK, this person who does that quality check. You go to a very low level, but then you have to but there's. Only one of the few ways to really handle the complexity of the server." – D11 (Respondent P1)

"Project the project manager and his package, managers and engineers and leads. So every person should be is responsible for every package with that schedule" – D4 & D12 (Respondent: S1)

19. Project Duration – Following the WBS level of detail (detail into activity level); monthly update on schedule variance

"We go quite high level, yeah. You do your breakdown. Let's say the the breakdown structure is quite high level, yeah. That's the first layer where you can make package manager, so you make package manager, yeah, responsible or a package and the package is your first layer of operator structure." – D1 (Respondent M1)

"On an acceptable level, so I tend to go more to level 4, no deeper than that." – D4 (Respondent S1)

"Like I did that on a monthly basis. And and we actually do that for all the projects on a monthly basis" – I3 (Respondent C3) (Respondent asked about monitoring forecast at completion)

20. Size in Capex – Following the WBS level of detail (detail into activity level)

"Now we go to the deepest level because we need to, like, get us to those various levels." – I2 & I5 (Respondent C2)

21. Incompatibility between different pm method and tools

"If you go into disputes with the client on elements of the contract where you have a difference of opinion on and. It is good to have a good backlog of data and records that you can look back on later because anything that you don't report you cannot prove that's all" – D4 (Respondent S1)

"Our weekly effort, we have a meeting. That's purely also to stay on track on the same page on all the elements of the project that you're that you're discussing in client communication, health and safety reporting" – D4 (Respondent S1)

22. Dependencies on external stakeholders – having quarter report to external

"So there's lots of different reports which measure non financial things as well this CO2. So there's lots of different reports and non financial in the in the quarterly report" – I2 & I5 (Respondent C2) – Indicating reporting non financial to external party and request

23. Number of external stakeholder – having quarter report to external and to update supplier rate

"So there's lots of different reports which measure non financial things as well this CO2. So there's lots of different reports and non financial in the in the quarterly report" – I2 & I5 (Respondent C2) – Indicating reporting non financial to external party and request

"That's why we have the three monthly financial the quarterly financial reporting where you can adjust any changes to the tax regulations or supplier rate increase or inflation that you can adjust it." – C2 (Respondent S2)

24. High number of task – breakdown project until activity package (following WBS level of detail)

"I think looking back, I also took it more on the Level 4 there in the (D12), I look more in detail because we're managing really took sometimes elements to work very up close, which is yeah, which is very that you look for example." *– D12 (Respondent S1)*

"Now we go to the deepest level because we need to, like, get us to those various levels." – I5 (Respondent C2)

"We go quite high level, yeah. You do your breakdown. Let's say the the breakdown structure is quite high level, yeah. That's the first layer where you can make package manager, so you make package manager, yeah, responsible or a package and the package is your first layer of operator structure." – D1 (Respondent M1)

25. High variety of task – Detailing work until activity package (following WBS level of detail) and approval mechanism

"I think looking back, I also took it more on the Level 4 there in the (D12), I look more in detail because we're managing really took sometimes elements to work very up close, which is yeah, which is very that you look for example." *– D12 (Respondent S1)*

"We go quite high level, yeah. You do your breakdown. Let's say the the breakdown structure is quite high level, yeah. That's the first layer where you can make package manager, so you make package manager, yeah, responsible or a package and the package is your first layer of operator structure." – D1 (Respondent M1)

"…and all always this depends on the cost and the impact. If it is, we have to do more meetings or we have to think as as soon as cost involved, it needs approval from the project manager of significant cost. However, there's always also. QHC manager which reviews the measures and the QHC manager is discussing it with the project manager are these measures sufficient." – D1 (Respondent M1) – Series of approval mechanism

26. Dependencies Between Task – Having daily report and one person to responsible on each activity

"I use my DPR as my daily progress reports to see how many cables are installed, how many foundations are installed, etcetera" – I2 & I5 (Respondent C2)

"Other tasks in my daily work did more in the Middle East was focused more on practical element of the operational phase of the works. We had a planner that overlooked the entire project, including the engineering" – D12 (Respondent S1)

"Basically, we would like to see a. Accountable person for a work package and you could assign responsibilities to various work packages or work package activities." – D11 (Respondent P1)

27. Uncertainty in method – Having daily report to update plan

"So we did daily with the team internally an half hour, not more, just half hour and every teamlead set what's he doing? If he saw in the interfaces as soon as they were identified, they were parked…" – D1 (Respondent M1)

"A daily meeting is. Yeah, for that. That is usually a meeting. That takes no longer than half. An hour in the morning. Before you start to work. Just to get on the same page. With everyone and and it is also a means to get to be engaged on the same topics" – D12 (Respondent S1)

28. Involvement of different technical disciplines – Regularly recalculating project budget quarterly

"Direct to the item like cement or fuel, because that can change and taxes might also be changing on materials. That's why we have the three monthly financial the quarterly financial reporting where you can adjust any changes to the tax regulations or supplier rate increase or inflation that you can adjust it" – C2 (Respondent S2)

"What I'm used to do is normally you do to the you take the budget. OK, as a sort of fixed and of course you have to normalize it to the to the new. Price levels, but in basically say the budget remains the same and we always refer back to a price level of, for example, If you now start a project, you always refer back to the price level of 2023, so you always can compare your original budget with your new budget and all these." – D11 (Respondent P1)

29. Conflicting norms and standards –

"Yeah, I developed documents and produce dashboards back then. That represented basically the essence of the extent of progress that we wanted to see for every project that I made" – D4 (Respondent S1)