Benchmarking Performance of Offshore Construction Projects

A case study for creating a suitable benchmark for AJS offshore construction projects on the ONEgas gas assets in the Southern North Sea.

Keywords: Benchmarking, Performance Indicator, Offshore, Complexity, Success factors

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Preface

This Master Thesis Report presents the results of an investigation into the subject of performance measurement in order to create a Benchmark. The study is performed during an internship at the Projects & Control department of AJS Leiden. The Master Thesis Report is the final assignment of the System Engineering, Policy Analysis & Management Master’s degree at the faculty of Technology, Policy and Management at the Delft University of Technology.

I extend my gratitude to Peter Bassie and Danny McGoun for the help and honest comments during my time at AJS. They allowed and motivated me to walk and talk freely within AJS until I found what I needed. I’d also like to thank my faculty supervisors, Mark de Bruijne en Floor Koornneef for helping and correcting my search on the line between science and practice. They have always been available for which I cannot thank them enough.

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Summary

Since the rise of oil prices in 2007, the difference in gas prices between the US and Europe has increased steadily. The pressure to efficiently produce and maintain gas assets has thus also increased. On top of these external trends, ONEgas strives to be in the top quartile companies in the gas market. The integrated contractor of ONEgas, AJS, is stimulated to continuously improve their performance. Currently projects are evaluated separately on changing aspects. A comparison of projects based on their performance assessment is thus not reliable.

This research proposes a benchmark tool for AJS to compare and signal performance. The corresponding analysis provides arguments in discussions around the performance of AJS. It was found that performance can be monitored by using the Project Management Triangle and controlled by acting on the comparison of the different projects with regard to the size of a project. The Project Management Triangle consists of Cost, Schedule, Scope and Quality as universal performance indicators. It is used to ensure comparability among projects in the Benchmark. The provided method for the selection of appropriate data can be used for the creation of a benchmark of other (unrelated) projects.

The AJS benchmark is created in such a way that time, effort and required knowledge are reduced to a minimum. The required data is however only available after the project has completely been finished. It is therefore advised to incorporate the benchmark as one of the very last actions in the close out process.

When monitoring and acting on the measured and compared performance it is important to keep the seven paradoxes in mind. When these are disregarded the action may very well have the opposite effect. It is thus advised to only use the benchmark as a signaling tool and have a separate study on how to improve a specific situation.
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CH 1. Introduction to Offshore Natural Gas in the North Sea

The difference in gas price between Europe and the US has been increasing in favor of the latter since 2006 as is visible in Figure 1. There are two reasons for this, first of all the huge impact on extraction cost of shale gas via new techniques like fracking. The recently cost efficient extractable shale gas has led to a recalculation of the gas reserves in favor of the US. Secondly, the cost of further extracting gas out of the, up to 40 years old, European wells is steadily increasing (European Commission, 2013; International Gas Union, 2011).

One of the larger extractors of natural gas is ONEgas. ONEgas is responsible for 54 Shell assets out of the total of the 180 gas assets in the North Sea (AJS, 2007) and strongly affected by the current developments in price. The current work process and assets are thus pressured to become more cost efficient. The existing assets are consequently adjusted to deliver more cost efficiently. With this in mind, ONEgas asseses the maintenance, modifications and creation of assets. The maintenance and modifications of ONEgas assets are done by their integrated contractor AJS. More on ONEgas and AJS can be found in 2.3.

Edward Merrow, the director and founder of Independent Project Analysis (IPA), concludes in his 2012 paper that oil and gas companies across the globe all seem to push for an unobtainable speed to first oil/gas. This drive for speed leads to unrealistic schedules and corresponding budget growth. From an analysis of 318 oil and gas projects he concludes that they are 7% more likely to slip schedule and 10% more likely to overrun cost than non-oil and gas projects. IPA is specialized in producing averages on ratios and performance indicator scores for any industry sector. They also provide improvement classes for company representatives to learn improve their performance. The data for this analysis is delivered by the IPA member client companies. It is important to note that offshore construction projects are only faintly comparable to regular onshore construction (Merrow, 2012; Sammelius, 2014; McGoun, 2014a). Whereas they both concern realizing a structure, offshore projects have a number of limiting influences to be taken into account during construction.

1.1. Additional Influences on Offshore Projects

On top of the factors influencing the construction work, offshore projects have additional influences. The factors effecting the construction are the space available to build, available budget, size of the structure and time. For infrastructural projects, politics will also play a major role (Morris & Hough 1993). Once these have been established with the client, construction is started and the client is often only contacted on a (long) periodical basis. The project processes of AJS are, as will be further described in chapter 5, more complex than the onshore construction projects. They involve the traditional construction estimations, engineering and execution work. Offshore projects are however made more complex due to the factors like weather, limited capacity, high cost of transportation, changing client wishes and effects of other work/projects. Each is detailed below.

![Figure 1 Natural Gas Import Prices (IEA, 2013) **LNG, ***Pipeline](image_url)
Wind

All construction materials and workers will have to be brought to the platforms either by helicopter or ship. Due to the offshore locations, the external effects have a bigger impact on projects than onshore. The salty water increases the occurrence of corrosion. The large unobstructed water surface allows fast and strong winds and quicker weather changes. The weather needs to be suitable to safely land a helicopter or heave over the load of a ship. Waves affect the ability of ships to maneuver and heave materials from deck onto a platform. Large waves and wind can thus delay a ship or the delivery of the materials to a platform. As can be seen in Figure 2 the mean wind speed is pictured. The mean wind speed in the North Sea increases further North (Riso National Laboratory, 2011). Generally the mean wind speed increases with the distance from the coast (ECN, 2004). The further a platform is from the coast the stronger the wind and the higher the waves can be and thus pose a higher risk of disrupting the transport by helicopter or vessel.

Limited Capacity

Before the equipment, materials and people can be put on a platform, checks are made to ensure the platform has enough space to store the materials and equipment and house the workers. Beds are limited on a platform and need to be scheduled in advance. Work can however be delayed due to less than desired beds and thus fewer than required workers available. In a similar fashion the places on the ships and helicopters are scheduled. The speed of work offshore is thus dependent on the available space at and to the platform as this determines the number of workers. The scheduling of space is handled by ONEgas. ONEgas can decide to reschedule or change priorities at any moment, immediately changing the available and/or assigned capacity. AJS can only apply for space but is not given any insight into the scheduling or priorities of ONEgas (Bassie, 2014a).

High Cost of Transportation

After a recent series of accidents the Civil Aviation Authority in the UK (CAA) will, per the first of June 2014, restrict the flight of any helicopter without floating devices to an offshore location when the waves are 20 feet or higher (CAA, 2014). This can be the case from winds starting at 15 mph but more likely with speeds of 45 mph depending on the overall sea conditions. As the mean wind speed increases further from the coast the measure will impact an estimated 6% of the flights (Scotsman, 2014). Transport to the platform will thus be more expensive as helicopters need to be equipped with floating devices.

Shipping costs are high due to the need for specialized ships to perform the work on the platforms. Such a ship, the Seafox 4, is pictured in Figure 3 on the right in bright red with the yellow cranes. The specialized ships are often large to provide sufficient working space and must remain stable (horizontal) in the exact same place, in order to perform the work.

The cost involved in the (rental of) transportation of material and workers can amount to 75% of the total project cost (Bajema, 2014). Given the large share the transportation has in the total cost, transportation time is minimalized and ships are scheduled to be used to their maximum efficiency.
Impact of Missing Parts

Given the distance to the shore and the resources needed to bring someone or something to the platform, missing out on a part or equipment will cause a delay. This applies for the largest as well as the smallest parts or pieces of equipment. Even when a screw is missing work is delayed because it is not possible to drive quickly down to a local store in order to get a screw.

Having the workers wait on the platform in their offshore time further increases the cost. Not to mention the effect the delay might have on the next project any of the crew or resources are scheduled for. It is thus key to set things up right from the start.

The maximum use of resources together with stringent scheduling and strong influence of the weather makes the transportation very vulnerable to delays. Any delay in a project will directly affect the next project as the resources cannot be released as planned from the previous project.

1.2. Changes to a Project by ONEgas

An analysis of projects has shown that on average a project is adjusted at least once, with an average of changes per project. The mean however is equal to one, as can be seen in Figure 5. Changes are registered per Project Change Request form (PCR). The changes result in far more than necessary work to realize a project as shown in Figure 4. Starting from point A the decision is made by the client to move on as planned to point B. The job is started with a study, followed by a detailed design in order to start execution of the job. For the execution the materials are packed in order of use in so called work packs. This packing order minimizes the space needed for the offshore unpacking of the materials. When done correctly there can also not be any confusion in what part to be used where as they are packed in order of use.

At a certain time however the client might decide to add a feature to the job (Change Effect Point 1 (CEP) in Figure 4) and change the end goal from B into C. This can have many reasons, for example that a similar part has proven faulty on another platform and thus needs to be replaced on all platforms. This however requires a plan for replacement, the appropriate materials and an additional part in the work packs. These work packs might also need revising as they are packed with materials ordered according to their use on the platform. The work is then continued toward point C. According to the ISC all spend hours are reimbursed. ONEgas thus pays for all the work rendered useless by the change.
Then close to arriving at the end goal C, CEP 2 occurs. Again this can have various reasons. In this case it is assumed that due to the increased costs, the job costs more than the specific rig produces in value. Unnecessary parts need to be cut from the job in order to decrease cost. Again the plans are adjusted, work packs have to be redone and now unnecessary hours spent must be paid to arrive at the final goal D.

The paid path from A to D now is a sum of all green and orange full colored arrows. The direct path from A to D is however far shorter as can be seen at the bottom of Figure 4. The estimate (dotted lines) has been revised twice and the original estimate cannot be compared to the actual cost. This is due to the changes made on the job. The original estimate was on a different project compared to what was delivered. It is thus important to compare the adjusted estimate and approved changes with the actual cost.

Along with the increased cost and time needed to deliver comes decreased motivation of employees and lack of confidence in future plans. The demotivation is caused by the adjustment of work, often requiring more work to check all the interdependencies. The motivation is hard to measure but where many changes are made in a project the employees can be reluctant to make an extra effort and more likely to await a final change. The lack of confidence in future plans is a direct result of the experience of the temporality of plans. Research of Cost Reports has shown an average growth of 100% due to changes.

The additional paperwork necessary for the changes is a blessing and a curse at the same time. The changes to the project are described on paper and signed by multiple employees of AJS and ONEgas for approval and acknowledgement. The description will show in great detail what has been changed at what time. Such descriptions are called Project Change Requests (PCR). The level of detail is suitable for auditing as it allows a recap of the events as they occurred. On the other hand the paperwork describing the changes and gathering of the signatures takes time. This time is often not available due to the previously described tight schedules and the need to quickly perform a change in end goal. Apart from the additional work to be done by the Disciplines the administrative workload is also increased with every PCR. Every change in a PCR needs to be managed by the respective Project Engineer (PE) and team leads in order to take full effect. The hours spent on Project Management thus increase for every PCR. An increase in PCRs will thus result in a corresponding increase in management hours.
In order to increase the efficiency of the engineering work processes, the current performance of these processes has to be measured first. The measurements can then be compared to other AJS jobs in order to establish how good the performance of a project is. Given the complex construction processes and several influencing but unpredictable factors, measuring the performance of AJS jobs is not a simple task. Currently AJS has no standard for the benchmarking of projects. ONEgas thus compares the performance of previous jobs based on their experience with the project. This results in an opinion, rather than substantiated facts, of the performance of a project. Neither ONEgas nor AJS can however show in figures whether the project performance is changing. An analysis instrument can provide this information. A more detailed benchmark can even compare projects on specific cost or booking references. As such it can provide figures on predefined ratios such as for example Project Management hours over engineering hours. In a similar fashion the cost can be compared. Since ONEgas values being in the top quartile and is the sole customer of AJS, it is important for AJS to have figures ready to support and show they are improving. In order to be able to compare projects and establish whether or not the performance has improved, the project performance indicators first need to be determined. The literature research has focused on finding a robust set of performance indicators.

1.3. Literature Research

Over the past 40 years a large amount of literature has been devoted to measuring project performance. However, the research on performance measurement in projects has to now not resulted in universal performance indicators due to the varying characteristics of projects and processes. Many authors agree that cost, time and quality, often indicated as the Iron Triangle, are to be included as success criteria in any project performance analysis (Atkinson, 1999; Turner, 1996; Morris & Hough, 1987 & 1993; Wateridge, 1998; de Wit, 1988; Pinto & Slevin, 1988; 1989; Saarinen, 1990; Ballantine et al., 1996). They also agree that these three success criteria however not exhaustive to determine the performance. Additional criteria need to be identified and added per project. The question what these criteria might be fuels an ongoing stream of scientific research.

Performance and success are closely related and often used by a client for the same question: Am I satisfied with the result and how it came to be? De Wit has concluded in his research that success is a matter of perception and thus, much like beauty, is in the eye of the beholder. “Therefore, to think that one can objectively measure the success of a project is an illusion.” (de Wit, 1988). He does continue stating that, even though an illusion, it can provide powerful lessons learned. Given the importance to keep the only AJS customer satisfied, success and performance indicators were both taken into account for the search into suitable additions to the Iron Triangle.

Additionally large amounts of literature have avoided the point of what to measure and described the (perverse) effects of performance measurement. Often a situation is described where by measuring performance, the situation stays the same but the measurements show a high performance. This can be the case when for example, an employee is judged on the number of tasks he performs. The employee can split his work in a large number of subtasks. This would result in a high performance but the same work output as before. He could also choose to do the little tasks only, effectively increasing his performance but avoiding all larger jobs which may strongly affect the quality of the work. Both are undesired situations. If the performance measurement is used comparable effects need to be mitigated.

With the clarified measurements and side effects of project performance, different projects can be compared. The comparison or benchmarking of projects is necessary to tell whether a project is doing 'good' or 'bad'. The words good and bad are in inverted commas due to their subjective nature. They both depend on the average in a set of projects. Comparing a bad project to projects which perform even worse will classify the bad project as best. Likewise for a comparison with projects which outperform the bad project. The project portfolio against which a project is compared should thus be set up in a suitable way.

Given the difficulties with selecting performance indicators and establishing a suitable and quick benchmarking method, AJS, via Jacobs, requested the creation of a standard benchmarking tool. As a Jacobs intern at AJS, I am expected to analyze the system, stakeholders and respective targets in order to produce a useful benchmarking procedure for AJS projects. To balance the practical and literature side of this Master Thesis the report structure is set up as the situation was approached.
1.4. Report Structure

At the start of the research a basic understanding, as can be found in the previous paragraphs, was gathered from internal documents, interviews, SEPAM knowledge, discussions with mentors and a small literature review on performance. This basic understanding was then processed into research questions, which are stated in the second chapter. The actor analysis in chapter 3 provides a better insight into why AJS the problem owner is.

After the more practical part chapter 4 will dive into the literature on Complexity, Benchmarking, Performance Measurement and Quality Management. The literature on these topics is consulted on definition and explanation or when applicable sub factors. For each topic the link to AJS is made. From the literature the most applicable methods, parts or factors are selected. Chapter 5 adds an elaboration on the project phases, processes, categories and concludes with relevant projects and available AJS data. Chapter 6 describes the (interpretation of) requirements AJS has for a benchmark and how these are handled. Given the available AJS information and the most suitable methods, chapter 7 proposes a benchmark for AJS. Here all the aspects found in literature or in the analysis will be taken into account. Chapter 8 wraps up the report with the Conclusions recommendations, reflection on the research and benchmark and future research possibilities. In order to prevent repeating information or storyline parts and lengthening this report unnecessary the detailed conclusions of a chapter are found in chapter 8. When the answer to a question can be found in a chapter, it will be listed in the concluding paragraph without the answer. For a list of abbreviations the reader is referred to page 60.
CH 2. **AJS Research Question**

AJS was asked by ONEgas to improve upon previous performance in order to stay in the top quartile of the market. There is however no general benchmark of projects by ONEgas or AJS. It is thus hard to tell whether the performance of AJS on the projects is improving. This leads to the main research question:

*How can the performance of AJS’ complex engineering construction projects involving maintenance and modifications of gas assets in the North Sea be monitored and controlled?*

Due to the general applicability of the main research question it is split in four sub questions and corresponding tertiary questions in order to specify the research goals. The four sub questions target the specific subjects of current AJS project performance, literature on performance measurement, interpretation of research findings and comparison of projects. The tertiary questions focus on specific parts of the according subject. The division in parts and subjects provides the answer to the main research question with a specific answer.

### 2.1. AJS Research Sub Questions:

1. **How do current AJS projects perform?**
   1.1. What are the general characteristics of AJS Projects?
   1.2. What AJS project data is recorded and available?
   1.3. How is AJS project performance measured by AJS?
   1.4. What (key) factors influence AJS project performance?
   1.5. Who controls the influencing factors?
   1.6. What side effects does the AJS project performance measurement lead to?

2. **How can the performance of AJS projects be compared according to literature?**
   2.1. What performance indicators from literature are suitable for AJS projects?
   2.2. How can the AJS project data provide the required information as required by literature?
   2.3. How can the AJS performance be influenced according to literature?
   2.4. How does literature propose to counter the perverse effects of performance measurements on AJS projects?

3. **How can the research findings be interpreted?**
   3.1. How can the findings on current AJS project performance be interpreted?
   3.2. How can the findings on performance measurement based on literature be interpreted?

4. **How can AJS project performance be compared to other (AJS) projects?**
   4.1. What AJS project performance indicators can objectively be compared?
   4.2. What tasks need to be performed in order to derive the AJS project performance indicators from the available AJS project data?
   4.3. What purpose can the AJS benchmark serve for AJS?
   4.4. How can the AJS benchmark best be implemented?

The research takes an empirical approach towards the research question and deliberately starts with the situation at AJS. The first sub question focusses on the current situation. The general characteristics of the projects are used to explain the difference of AJS projects compared to ‘regular’ construction or maintenance projects that are usually referred to in literature about project engineering and performance management.
Next the recording and availability of data is looked into in order to clarify what data is recorded and when it is available to AJS. Then the performance measurement by AJS is analyzed in order to determine the current AJS performance indicators. Accordingly the influencing factors of the performance indicators are studied. Research into this subject at AJS determined who controls which factors and how these factors influence the performance of AJS projects. This part of the research is further elaborated in 2.3 Given the who, what and how on the influencing factors, the (side) effects of project measurements can be mapped. This mapping can then be used to highlight the possibilities and likelihood of distortion of said performance indicators.

The second sub question addresses the theoretical approach to performance measurement. It starts by searching for the most common used or proposed performance indicators for construction projects in literature. These performance indicators are then tested for their suitability given the AJS project characteristics. When the appropriate performance indicators are identified, the focus can turn to how this information is retrieved from the available data. The specifics of who will have to do what on the task of retrieving the data is discussed later under sub question four. Similar to the first sub question the possibilities of distortion of the AJS project performance is assessed by looking into the influencing factors. Then literature is searched for ways of prevention such distortions of the AJS project performance.

Sub question three looks into the interpretation of the research findings by reflecting on the answers found in the two previous sub questions. The current situation is discussed by first by diving into the current performance management and the corresponding data and consequences. Secondly a similar approach is taken for the literature part in sub question 4.2.

The last sub question dives into the practical part of project performance measurement and the comparison of projects. The performance indicators will be discussed on comparability among other projects at AJS. The aim is to find a number of robust performance indicators which can be measured or derived from the AJS project data. When these AJS performance indicators are clarified, the specific task(s) of how to collect the needed data for the indicators is looked into. Per task will be reviewed at what point in the project this can best be measured and who will supply the required data. It must be clear what information will be stored in what data format and by whom this will have to be done, at which time in the AJS project. Then the use and purpose of the benchmark for AJS data is analyzed. The analysis will indicate who is most affected by the AJS benchmark and how they might adjust their behavior. These influences and dependencies will be taken into account with the implementation of the benchmark. The aim is to make a simplistic and pragmatic to use benchmark (procedure) which requires minimal effort and deviation of the current tasks.

2.2 Qualitative Research

This is a qualitative research into the performance measurement and comparison of the performance of AJS projects. It will provide a framework of methods to find the used performance measurements in an organization and from there determine possible additional performance measurements. The framework will also take the side effects of performance measurement into consideration and strive to reduce them to a minimum.

An ideal research would have all data available. As all conditions are known the conclusions of such a research would always be true. This is called deductive reasoning. In reality the required information might not be fully available, not to mention all information on the subject. One can make an (educated) assumption on the missing data but this still offers no 100% guarantee to the truth. Basing conclusions on several observations with the assumption that all other observations are equal is called Inductive reasoning. Due to not having all data, it cannot be said if the conclusion is 100% right. It can thus be wrong. Inductive reasoned results can be logically concluded and applicable but, the conclusion may be proven wrong when additional information comes available. Any researcher will try to approach a deductive reasoning but will at best only be able to present an inductive reasoning with a large number of arguments.

For scientific purposes a generalization of the conclusions is desired. Generalizing deductive conclusions is simple because they are always true. Generalizing inductive reasoning can only be done with great caution due to the possibility it may not be true. The conclusions and results could however still prove useful for future research on performance measurement when the characteristics are carefully taken into consideration.
To provide the research with a substantial basis for the inductive reasoning a number of methods are used. The different methods are used to analyze the organization and its means and ways to measure AJS project performance. For example a literature study has been performed on the three closely related subjects; Performance Measurements, Benchmarking and Effects of Performance Measurement. Additionally the relevant actors with their interests and influences were mapped.

Summarized it can be said that in the first instance this research provides a framework to analyze the performance measurement and its effects in an organization. Secondly the exact results might also be compared to other projects when the characteristics are taken into consideration.

2.3. Specific Analysis and Research

The available information within AJS was indexed to have an understanding of what was available and where it can be found. This eased the search of data and people later on in the research. Such an index was created for the Actor Analysis, Project Data Analysis and Literature Research on Performance Measurement and Benchmarking. By indexing the available data it will be clear in an early stage what information is missing and where that might have been found.

The Data Analysis focused on the gathering, separating on relevance and processing of all AJS project data. First the setup of the company is studied in order to establish stakeholders and their priorities as well as a mapping of the work. Secondly data on projects is gathered and processed into an Excel spreadsheet. The Excel spreadsheet will need to include robust and correct formulas to show the information needed on Cost and Schedule. This information will be used to assess the performance of the projects so it can be benchmarked.

Interviews were held with a dozen people, selected based on the projects they worked on and information they handle. The purpose of these interviews was to ensure the required data was available and interpreted correctly. The interviews have further clarified the information found in the Data Analysis. In any case they will be asked to elaborate on excesses found in the Data Analysis and give their view on how the excess came to be in that particular project. Additionally the data was verified and validated in the interviews. This was done by asking experienced employees to break down the provided data. The breakdown provides insights into how reliable the data is, where it is located and how it can be processed with a minimum effort. As explained in the Data Analysis the data was gathered and mapped. This was a continuous process where the newest data was directly incorporated into the mapping of previous data. The results of the analysis were put against the results of the Literature Research.
CH 3. AJS Involved Actors

In the case of AJS a number of actors are involved in the business activities. The actors and relations are displayed below in Figure 6. The arrows indicated the stake of companies in that respective company. The actors will be introduced in order working from the middle outward of Figure 6. It will start with ONEgas and then further detailing the left half of Figure 6. Then the right half will be further elaborated upon in a similar fashion starting with AJS then working to the right of Figure 6.

Focal point of the research will be the red selected area in Figure 6 because of the Internship at AJS and the Integrated Services Contract (ISC). The ISC has the direct consequence that AJS is integrated into ONEgas rather than only acting as the main contractor. In Figure 7 a map is given of the ONEgas facilities and pipelines. The map is shaped in order to display most ONEgas assets. Additionally an East-West border is added to display the respective work area of the UK and NL department of ONEgas and AJS. A larger version of the map without additions can be found in Appendix A: ONEgas Map Facilities and Pipelines.

Figure 6 Full Actor Network

Figure 7 Adjusted map of ONEgas Facilities and Pipelines. Note: Geographically incorrect (ONEgas, 2013a)
3.1. ONEgas

ONEgas owns 51 assets off- and onshore in the Southern North Sea responsible for the extraction and processing of 25% of the natural gas in the Netherlands (Shell, 2013). ONEgas is owned by Shell and NAM and has a fixed annual budget for modifications, maintenance and new projects. ONEgas wants to realize as many projects as possible from this limited budget (AJS, 2014a). Any increase in cost of any project thus directly limits the resources for other projects. Shell has a strong influence on ONEgas and pushes it to be in the top quartile in the market. ONEgas will in some case be referred to as “client”.

Currently ONEgas targets all non-essential work processes and functions in finding a balance between cost of failure (not dangers or safety risks!) and cost of the so called Project Management functions. In paragraph 3.5.5 the specific functions of Project Management are listed.

3.1.1. ONEgas Stakeholders

ONEgas is a 50% joint venture of NAM and Shell, specifically Shell Expro. As no other Shell group is involved, Shell Expro will be referred to as Shell. The relations are shown in Figure 8. Due to the Integrated Services Contract (ISC), AJS is involved as an integral part of the ONEgas organization (AJS, 2014a).

The ISC allows AJS to appoint their own director from their ranks rather than have a Shell or NAM employee do the job. AJS provides the maintenance and modifications of the offshore assets and gas plants.

3.1.2. ONEgas Assets

The ONEgas assets contain 90 producing fields serviced by 51 offshore installations in the southern part of the North Sea and two onshore gas plants. One gas plant is located in Den Helder (NL) and one in Bacton (UK). The assets are connected through over 1,200 kilometers of pipeline. A map of the ONEgas assets can be found in Figure 7. The gas production of the platforms is send to the gas plant in the respective country (AJS, 2014b; AJS 2007). ONEgas is responsible for 25% of the total gas production in the Netherlands (Shell, 2013).

As shown in Figure 7, the assets in the North Sea are thus divided geographically between East and West of the North Sea also known respectively as NL and UK. Where all assets in the West half deliver gas to Bacton and all assets in the East half deliver gas to Den Helder. This separation can easily be traced back to the geographical division of the assets on the respective National territories of the UK and Netherlands. The operations and work in the Western half is largely managed from Great Yarmouth whereas the work on the East part is divided among Leiden and Assen.

3.1.3. ONEgas Integrated Services Contract

The ISC allows AJS to appoint their own director from their ranks rather than have a Shell or NAM employee do the job. AJS provides the maintenance and modifications of the offshore assets and gas plants.
3.1.4. ONEgas Organization

According to the ISC AJS is an integrated part of ONEgas. This is visualized in the organogram displayed in Figure 9 where the AJS team is shown in white.

Figure 9 ONEgas Integrated Leadership Team (ONEgas, 2013b)

3.1.5. ONEgas Budget
3.2. NAM

NAM stands for Nederlandse Aardolie Maatschappij (Dutch Crude Oil Company) and was created on 19 September 1947 by Shell and Esso. Each parent company has a 50% interest. Together they joined forces for the exploration and extraction of crude oil and natural gas from under the Dutch soil. The main office of NAM is located in Assen. As Esso was acquired by ExxonMobil that stake is now in their possession (ExxonMobil, 2012). A visualization of the division of interest is displayed in Figure 10. However, in practice, all employees and documents issued by the NAM seem to have their origin in Shell.

3.2.1 Influence of Shell

Being a subsidiary of Shell, the NAM uses the operational and safety systems and processes of Shell. This is visible from the Shell logo on documents when going through any procedural of safety related NAM-document. An example of this can be found in the left top corner of Figure 9. Any internal organizational program initiated within Shell will also be applied within NAM. This shows the large influence Shell has on the NAM and its organizational procedures.

3.2.2 NAM Offshore Assets

Apart from the land activities, the NAM currently owns 19 offshore locations, 4 monotorers and 500 pits offshore (in the Dutch part of the North Sea). All piping from these platforms comes onshore in Den Helder. The production of the Shell platforms in the United Kingdom (UK) part of the North Sea is routed to the Bacton gas plant in the UK.

3.2.3 External Financing

The NAM often cooperates with Energie Beheer Nederland (Energy Control Netherlands also EBN) for the financing of its projects. EBN is a company owned by the Dutch state and involved in nearly all oil and gas exploitation projects in the Netherlands. EBN usually contributes 40% to a project (NAM, 2014). The EBN is not taken into account in this research as their influence is not noticeable within ONEgas and thus hard to map or describe.

3.3. ExxonMobil

ExxonMobil is the world largest oil and gas company on the stock exchange and one of the largest petrochemical companies. ExxonMobil refineries in the Benelux can be found in Rotterdam, Antwerp and Kerkrade. The main Benelux office is located in Breda. It is also the mother company of Exxon, Mobil and Esso. The first and the last are consumer and business suppliers of vehicle fuels like gasoline, diesel and LPG. Mobil produces and performs research on engine oils and lubricants for industrial machines (ExxonMobil, 2014). Exxon Mobile received the 50% stake in NAM with the acquisition of Esso. Additionally it also has a 25% part in Gasterra which concerns the on shore gas activities in the Netherlands (ExxonMobil, 2012).
3.4. Shell

Shell is a group of energy and petrochemical companies based in The Hague. It has a 50% stake in NAM and a 50% direct stake in ONEgas. These relations are shown in Figure 12. Since the NAM is participating for the other half one could argue that Shell (in) directly owns 75% of ONEgas. Given the influence of Shell on the day-to-day practices and procedures in NAM one could even argue that ONEgas is fully controlled by Shell. What can be said for certain is that Shell is a major player in this field and should be taken into any consideration.

3.4.1. Shell Business Categories

Shell separates its activities in three categories: Upstream, Downstream and Projects & Technology. Upstream business searches, recovers and transports crude oil, natural gas and bitumen. Geographically a distinction is made between the Americas and the rest of the world. Downstream business manages refining, markets, trades and sells oil and chemical products for home or industrial use. It also oversees Shell's interests in alternative energy with the exclusion of wind energy. Projects & Technology manages the delivery of major projects and drives research and innovation to develop new technologies. It then uses this knowledge to provide technical services or technologies for use in the Upstream and Downstream business. Additionally, Projects & Technology is responsible for the leadership across Shell in the fields safety, environment, contracting and procurement (Shell, 2014). Due to the gas extraction and processing the ONEgas assets are considered an upstream division of Shell.

3.4.2. Shell Goal Zero

In 2007 Shell has initiated Goal Zero aiming to realize zero incidents (fatalities, spills, fires and accidents). A major part of the program is the three golden rules of Shell and the twelve Life Saving Rules as shown in Figure 13. This program is not restricted to Shell employees and compliance to the rules is demanded of any party working with Shell. Proven non-compliance with the Life Saving Rules is punished by termination of all contracts with the respective party and removal of the according employees from all Shell sites. The termination and removal is not limited to the project where the incident occurred but concerns all projects where the party is involved. Contractors are to comply with the Shell procedures on safety or not work for Shell (Shell, 2014). Safety is thus a key aspect in Shell and not disputed (AJS, 2014a).
3.5. AJS

AJS is a consortium of Amec, Jacobs and Stork. The three companies will be reviewed in detail in the paragraphs below. The ICS makes AJS responsible for the maintenance and modifications of ONEgas assets. Apart from the maintenance and modifications, AJS can also provide ONEgas with Capital Projects.

3.5.1. AJS Stakeholders

AJS is a joint venture founded by AMEC oil and gas, Jacobs Engineering Netherlands and Stork Industry Services Netherlands in 2003. The companies are from here onwards referred to as respectively Amec, Jacobs and Stork. Amec has a 50% share while Jacobs has a 12.5% share and Stork maintains 37.5% (AJS, 2007). This is visualized in Figure 14. All three companies have previous experience with the oil and gas industry, including working specifically with Shell (Jacobs, 2014b; Stork, 2014; AMEC, 2014).

AJS has an Integrated Services Contract (ISC) with ONEgas. The ISC actually forms the sole reason for the existence of AJS. That is, AJS has to exclusively serve ONEgas and ONEgas only. The ISC specifically limits the clients of AJS (AJS, 2014a). This reinforces the purpose of AJS as provider of maintenance and modifications solely to ONEgas.

There is a general division of work within AJS due to country specific regulations and transport time from the shore (McGoun, 2014). The division is made between East (NL) and West (UK). This division is enforced by the division of the work between the stakeholders. AMEC does all the work in the UK whereas the work in the Netherlands is split between Jacobs and Stork. This division of geographical area and work also shows in the percentage share of the stakeholders. A little specialization is calculated into this separation of work areas. NL for example takes care of all the flow line related work in the whole ONEgas area whereas the UK part has two other fields of expertise. Such projects are called cross border projects. They do not differ further from other projects and are treated as similar.

3.5.2. AMEC Oil and Gas

AMEC oil and Gas is a sector of AMEC. It is the leading provider of asset support to the oil and gas industry with engineers in over 200 facilities in eleven key oil and gas industry location worldwide. In 2008 AMEC received the role of duty holder over the Dunline cluster, previously owned by Shell, with an Integrated Services Contract (ISC). AMEC Oil and Gas has over 40 years of experience on projects in the North Sea and has worked on oil sands since the 1950’s. AMEC employs over 29,000 people in 40 countries around the globe. It provides its services to customers like BP, Shell, EDF, National Grid and US Navy. AMEC is listed on the London stock exchange (AMEC, 2014; AMEC, 2013).

3.5.3. Jacobs Engineering

Jacobs engineering is one of the largest and most diverse providers of professional technical services. It employs 70,000 people on 250 locations in 30 countries worldwide and nearly twelve billion dollars revenue in 2013. Jacobs focuses on relationship based business with 90% of the projects being from repeat customers. Jacobs provides engineering (project) management (Jacobs, 2014a; Jacobs, 2014b). Projects headed by Jacobs are diverse and spread all over the world from Chemicals to buildings. Some examples of projects of Jacobs are the ITER fusion reactor in France, the new Blackfriars station in London, San Francisco Bay Tunnel and the Chinese Academy of Sciences in Beijing. (Jacobs, 2011; Jacobs, 2012; Jacobs, 2013)

3.5.4. Stork Industry Services Netherlands

Stork Industry Services Netherlands is from origin an industrial machines manufacturer. The main focus is thus the management, optimization and installation of assets. This can include maintenance, replacement, relocation and (de)commissioning. Stork has 14,500 employees in 22 countries. The main product of Stork is equipment and services to this equipment (Stork, 2014). Within AJS Stork is responsible for the production, installation and packing of the needed materials, parts and equipment.
3.5.5. AJS Organization

The organization has adopted a matrix organizational structure consisting primarily of delivery and functional teams. This is displayed below in Figure 15.

At the top stands the General Manager, this function can be considered as the Director of AJS and accountable to the AJS Board for the financial performance and profitability of the business. This is measured against annual and long term plans and targets. The Business Improvement Manager and SHEQ Manager provide the leadership team with organizational support and advice.

Second from the top are the Heads of Capital Projects and E&M. They are responsible for the effective and safe delivery of the maintenance, modifications, operations, support and execution of capital and upgrade project activities to the various ONEgas assets.

The functional teams consist of the Technical Services, Maintenance and Business Services. The respective Managers are liable for the provision, integrity, reliability and availability of services and systems in order to enable safe and effective business delivery.

In any project started a number of functions need to be fulfilled in order for the project to be run according to the agreed procedures and reach the level of quality desired by ONEgas. These positions are: Project Engineer, Cost Engineer, Planner, Document Control, Construction Manager and the respective Disciplines needed for the job. The exact composition of the Discipline team depends on what the job is about. Take for example the replacement of the wiring on a platform. The Discipline Team on this job will likely exist of some Electrical, Process and Instrumentation Engineers but certainly not any Piping Engineers.

A Cost Engineer and Planner are responsible for updating respectively the Cost Report and the CTR Manhour Summary. This data is used by the Project Engineer to keep track of the expenditures and progress of the work. Document control is only needed for the processing and archiving of documents in order to make them available to the Project Team. The Construction Manager supervises the Discipline work in depth, looking into the what and how of it (Hartmann, 2014).

3.5.6. AJS Jobs

Within AJS three kinds of jobs are distinguished: Maintenance, Mods and Capital Projects. The Capital projects are also simply referred to as “Projects”. The main difference between the three categories lies in the ISC. This research only covers the maintenance and modifications (Mods) on the ONEgas assets.
The work to be done on either category is fairly self-explanatory; maintenance is any job that concerns the work needed in order to keep an asset running. This category is divided in preventative and corrosive maintenance. The first aims at preventing the asset from failing to work by replacing parts before they can malfunction. The corrosive maintenance is the replacement of parts that have malfunctioned (McGoun, 2014a). Mods focuses on any adaptation of an asset to new technology or design in order to lower the operational cost or of the asset.

The construction of new assets is not covered under the ISC and can thus be granted to either AJS or an external contractor. Such work is considered a Capital Project. An addition to the ISC can be made in order for AJS to take on the project. ONEgas can however also decide to grant the project to an external contractor.

Project performance is measured according to the requirements of the ISC. In the last decade this meant that projects were not allowed to overshoot the approved budget (estimate + changes and internal transfers) by a certain percentage. From this year (red. 2014) onward the performance is measured by achieving milestones. Per project phase and per deliverable a specific delivery date is set. This date and/or deliverable is discussed in meetings between ONEgas and AJS. The deliverables and dates are based on estimates of ONEgas and estimates of AJS. When the deliverable, an engineering drawing for example, is finished by the previously agreed date or before, the milestone is achieved. AJS receives a bonus for a minimum number of achieved milestones.

### 3.5.7. AJS Internal

A note is made on the three contractors forming AJS. While Stork has a different purpose in the joint venture, Jacobs and AMEC provide very similar services within AJS. There is however still a large difference. Jacobs provides the management and non-construction engineers in the Netherlands whereas Stork does the construction engineering. Amec does all of the above in the UK. For the research this means that comparable projects are more likely to be found in databases of AMEC or Jacobs if such data is stored. Seen from a competitor’s point of view, it can also mean that AMEC and Jacobs could compete with or learn from one other within AJS, in order to strengthen their competitive advantage in the market. However no such behavior was noticeable in the daily work or at any other time during the internship.

AJS has no personnel on the payroll, every employee is employed by the three founding companies and the salary is paid by these companies as well. The cost for these employees is then billed to AJS.

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<th>AJS Booking Positions (AJS, 2010)</th>
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Table 1 AJS Booking Positions (AJS, 2010)
3.6. Concluding on AJS Involved Actors

ONEgas is largely controlled and run by Shell. Direct signs are found in the use of the Shell logo on procedures and other documents as well as the participation in Shell programs such as Goal Zero. Safety is taken very seriously with stringent measures for violation of safety rules.

After previous experience with contractors Shell has set up ONEgas and contracted AJS by means of an Integrated Services Contract (ISC). Within ONEgas, AJS is an integrated department instead of a hired contractor. Due to previous experience with a different contractor, ONEgas focuses on eliminating any possibility of stretch in the budget.

AJS is a consortium of AMEC, Jacobs and Stork. The work is divided between East (NL) and West (UK). Jacobs and Stork divide the work in the East according to their specialization. AMEC performs all the work in the West. This division is also fed by the country borders, meaning other regulations in the two areas. The AJS jobs are split in three categories: Maintenance, Mods and Capital Projects. The first two category of projects are automatically granted to AJS through the ISC. The latter is to be won in a tender. Not winning the tenders on capital projects might cause unexpected effects to AJS.

Due to the integrated nature of the contract, communication and work between ONEgas and AJS should be easier and faster. In reality ONEgas information and decision are not transparent to AJS. Decisions by ONEgas may thus come unexpected and seem unclear to AJS. The irregularities can cause great changes and disturbances to the AJS work.

Compared to onshore construction projects, AJS has a multitude of more Project Management functions more. These extra functions are necessary to do the work.

This chapter provides an answer to the following four tertiary questions:
1.2 "What AJS project data is recorded and available?"
1.3 "How is AJS project performance measured by AJS?"
1.4 "What (key) factors influence AJS project performance?"
1.5 "Who controls the influencing factors?"

The answers are included in 8.1.1.
**CH 4. Literature Review**

In order to perform a proper scientifically based analysis, a literature study on the relevant topics will be performed. The relevant keywords to the topics are: Benchmarking, Performance Measurement, Managing Performance, Project Success Factors, Organization & Management and Quality Management. Search queries were entered in the following databases and search engines: Scopus, Web of Science, IEEE XPlore Digital Library, JSTOR, ProQuest, OvidSP, Narcis and Google Scholar. With the literature the scientifically optimal situation is determined. On top of the databases and search engines, books on organizational theory, benchmarking, performance measurement and management have been used to support the scientific notion. All notions on the topics in this chapter are based on the literature reviews unless specified otherwise.

The literature review is limited to the aforementioned key words as other keywords, such as: Offshore, Construction Projects and Construction Process, only led to studies which focused merely on cost growth or specific calculations on materials. Even though the cost aspect is an interesting topic it only confirmed the importance of cost as a performance indicator. The calculations on materials were of far to great detail to even aid the search for universal performance indicators. These and similar key words were thus excluded from the search.

From the search with the remaining key words, as mentioned in the first paragraph, a number of papers and studies were selected. This selection was based on the relevance of the studied subject and references by other authors. The relevance was determined by the number of similar keywords and similarities in study situation such as construction projects, offshore work and other factors elaborated upon in chapter 1. The reference to other articles were simply counted and when an article was mention at least twice it was, when relevant, included. Some of the scientific articles found were not used as a reference in this paper but, did provide important leads to other studies which were used in this report.

In order to create a full picture of the reviewed field of literature the majority supported notions were used in combination with minorities or even extremes. This was done to ensure that the situation of AJS does not apply for such an minority or extreme case and that the, by the majority supported notions, are suitable for AJS.

This literature research resulted in a number of conceptual analytical approaches and accordingly different solutions. These analytical methods have been tailored to fit the situation at AJS and will be presented later on in the report. The research addressed sub question two and its tertiary questions on the appropriateness, added value of and strategic behavior related to benchmarking, performance measurement and data requirements of projects in this specific situation.

Due to the size of the topics, one of the topics could be enough for a single master thesis, a representative summary rather than an exhaustive analysis will be provided of literature in each of these topics. The literature research will be split into parts to accommodate the different subjects needed in this research. The separation between Complexity, Benchmarking, Performance Measurement and Effects of Performance Measurement is made due to the extensive and large number of writings on the different subjects. Each subject will shortly be elaborated upon below in the aforementioned order.

The literature review serves to gather scientific approaches to the situation in order to analyze, assess and propose solutions. The purpose is to establish scientifically sound definitions of Complexity, Benchmarking and Performance Measurement in order to find a suitable solution for AJS. Most important is to find a generally applicable set of indicators that take into account the complexity of the work and allow comparison of projects.

### 4.1. Complexity

In order to correctly address the complex work processes, a definition of complexity needs to be established. This is done by means of a literature search on complexity in and of construction projects. From the literature found, Geraldi, Maylor & Williams (2010) gave the most recent published overview of complexity in literature since 1996. This overview was presented in a multipage table. Even though the phrasing of some of their research points can be questioned, follow up research of the author has proven the table to be correct. Additionally an article of Bosch-Rekveldt et al. (2010) on grasping project complexity
was compared on search characteristics and findings. As Bosch-Rekveldt et al. focus on the understanding of complexity by breaking it down into sub elements, the findings are not comparable. The literature used in the found review has a large similarity in authors and the same period time of literature (1996-2010).

It can be concluded from the comparison of the different studies * that among the many writings on project complexity, *2 a number of aspects of complexity are agreed upon by all. Some authors have different names for these aspects such as: number of tasks, number of activities, number of Disciplines, all focusing on the number of elements in a project.

Others bundle aspects and have a special name for it*2. For example, the concepts structural complexity, project and environmental complexity, equivalent to complexity are used where the focus lays on the size, variety and interdependence of the project elements. From Bosch-Rekveldt et al. (2010) the idea of elements is adopted. The term ‘elements’ is used in this research where project members, activities or Disciplines can be used. From the literature *2 it was concluded that though these three are different subjects the analysis on the size, variety, interdependency and uncertainty is the same. Fact is however that, according to the articles, (at least) the following four aspects are found to determine the complexity:

I. Number of project elements. – Large is more complex.

II. Differentiation of the project elements. – Many different is more complex.

III. Interdependency of the project elements. – Large interdependencies are more complex.

IV. The uncertainty of the project (elements).– Many or large uncertainties make it more complex.

It can be noted that these aspects all focus on the project elements. The characteristics of the elements thus specify the complexity of the whole project. One could even argue that a project is not complex, but rather the elements of a project are, but that is far beyond the Scope of this thesis. For the purpose of this Master Thesis the aforementioned four aspects of complexity will be used as a definition of complexity.

Many of the above mentioned aspects can be identified in the projects of ONEgas. Starting with number IV, AJS work at an offshore asset is dependent on the weather, which is however unpredictable at sea. Due to the fact that the work places are gas producing or processing, certain work can only be done when the facility or platform is shutdown. This however has a large impact on the overall gas production of the whole asset. Shutdowns are thus planned when gas is needed least, in the summer months. The time window for certain work is thus limited and fixed. As a consequence a planning can easily be delayed. This brings us to aspect III.

Due to the required support of ships, helicopters and construction workers to provide material, manpower and capable hands at the right time one can imagine that with limited availability of these resources one project can easily delay another. The interdependency of projects is thus large. On each of the 54 assets of ONEgas, no job is the same, hence aspect II. No job is, except on a very general level, the same simply because all the platforms and facilities differ in their physical form and lay-out. AJS distinguishes six different kinds of jobs for ONEgas with two kinds of maintenance. The differentiation of the work is thus quite big. The argumentation of aspect I, can be found in the elaboration on all the previous aspects. The work needs to be done on 54 assets in limited timeframes with limited availability of resources based on a strict but easily disrupted planning. There are quite a number of different project elements involved, over some of which AJS has no control. In addition to this comes the in chapter 2 described additional influences of offshore projects. One could thus make a strong case for the complexity of the work done by AJS.

* Geraldi, Maylor & Williams (2010); Bosch-Rekveldt et al. (2010); Omarova, Ireland & Gorod (2012); Ma et al (2012);
4.2. Benchmark(ing)

Comparing operations in or with another organization can give a good overview and even provide new insights for improvement. Hinton, Francis & Holloway (2000) have lined up three definitions of Benchmarking; the first of Coopers & Lybrand (1994), the second of the UK Government and thirdly the definition of Camp (1995). All three definitions focus on reviewing the processes in comparison with best practices. These best practices can be found either internally or externally. When the explanation of the specific benchmark types (Internal, Competitive, Functional and Generic) are compared among the papers of Hinton, Francis & Holloway (2000); Bhutta & Huq (1999) and Elmuti & Kathawala (1997), the comparison of data is described. There are no best practices or improvements involved, just a comparison. Further investigation showed that other papers* on benchmarking have a similar distinction which can be separated between the word Benchmark and the verb Benchmarking also called Benchmarking Process. One would expect that Benchmarking is the process of creating a Benchmark, literature research proved otherwise. From the aforementioned literature the definitions in Figure 16 are derived.

![Figure 16 Literature Definition of Benchmark and Benchmarking](image1)

Whereas a Benchmark is thus a comparison, using the verb Benchmarking (in orange in Figure 16) suddenly implies implementing some sort of quality management based on the results of the Benchmark rather than just creating the comparison. This combination of comparing and acting on the comparison seems undesirable due to the different required sphere of influence. Creating the Benchmark requires time and data. Improving upon an existing organization however requires time, data and approval of Management since the organization or its operations are changed. Additionally it should be taken into account that a Benchmark only shows a performance. First the cause of underperforming has to be investigated (over performing is often not an issue). Once the root cause has been established either a best practice can be implemented or quality management can be used to start continuously improving upon the situation.

Analysis on the root cause and solution is a logical step to take in order to answer the why and how of the underperforming operation as this can improve the performance. It is however arguable if this is automatically to be included in Benchmarking as there are several scientific fields such as quality or process management dedicated to improving operations. It can be assumed that the accumulated research in a scientific field provides far better expertise for a solution to a problem than a method incorporated in generally applicable benchmarking. For this report it is thus decided that the analysis of the (root) cause, its solution and its implementation is excluded from the definition of Benchmarking. For a similar reason the research fields on KPI’s and success factors are separated from the benchmarking. The specific fields can be consulted in order to establish what is best to benchmark in the given situation. Though making a benchmark and improvement are always linked, it is confusing and limiting to include the improvement into the process of benchmarking. The definition of benchmarking is thus narrowed down by excluding the analysis and improvement part. This new definition is displayed in Figure 17.

![Figure 17 Applied Definition of Benchmarking](image2)

The previously named literature on benchmarking, also added an important note on the similarity of comparing projects. When data is compared it is to be ensured that the data is the same and has the same meaning. For example, cost in euros cannot be compared to time in any form. Cost in euros can however
also not been compared to cost in dollar as the currency has different values. One might even take into account local economic value if the difference in value is very large, say between Europe and Africa. Calculating Ratio’s as a percentage of the whole may provide a solution. Otherwise the exchanges rates can be used to transfer into one common currency.

4.3. Performance Measurement

In order to compare projects, as described in the previous paragraph, some sort of performance indicators or success factors need to be determined. Construction projects are often considered both unique and similar in AJS as well as in scientific literature. This is best seen in the description of the so called “mega” or “major” construction projects described by Morris & Hough (1993) where they provide an overview and analysis. These projects always differ given the circumstances like political, economic or weather effects on a project but Morris and Hough compare them on general points. The debate on the comparison of such projects is a delicate matter given the different circumstances and the different effect of them. Given the similar nature of the work done by AJS as mentioned in paragraph 2.3, overall project performance indicators were found during a literature review on performance management and success factors.

4.3.1. Iron Triangle

From the reviewed articles\(^3\) on performance measurement and success factors it appeared that there is no consensus on a general set of key performance indicators (KPI) for projects. Atkinson (1999) points out that more than 40 years ago Oisen (1971) described the so called Iron Triangle (displayed in Figure 18) in compliance with the goal of Project Management; deliver agreed quality in time and within budget. Cost and Schedule are often described as resources and time available. Quality on the other hand is described as Scope or agreements on deliverables and is directly influenced by the input of time and resources. The perceptions can also differ on Quality when the agreement has been interpreted otherwise than the client expected. If there is a large difference the client could even see this as failure to deliver. The cost and schedule performance are measured by a ratio based on the same calculations. Below the calculation is elaborated upon with cost as an example.

Cost is often\(^3\) measured in the actual cost divided by the estimated cost minus one to show under budget as a negative. The resulting ratio is ideally 0%, anything above is a budget growth and below is budget shrink. Later changes to the project are however not accounted for in this calculation. Besides the previous calculation a second cost calculation is used: actuals divided by the sum of estimate, changes and internal transfers minus one. This calculation takes the changes and transfers into account. The difference between the first and second ratio can then be used to determine the Scope growth. Again due to the minus one budget shrink will now show as a negative percentage allowing quick signaling.

The quality measurement cannot be based on a calculation of some kind as it involves much of the perception of the client. Perception is much harder to measure and in literature it is often determined by means of an interview where the client is asked to grade certain aspects of the job and the team. What is asked differs however. Noticeable is the use of the Likert scale in most interviews in other studies.

4.3.2. Iron Triangle Fixed Parameters

Two parameters of the Iron Triangle can be chosen to regulate the third. The relations in the Iron Triangle are thus characterized as the “pick two”\(^3\) for a project since high quality requires much time and/or resources or vice versa for the other two. A project Manager can at best thus “pick two”. The third triangle point is the result of the other two.

\(^3\) Atkinson (1999); Baccarini (1999); de Bruijn(2002); Cokins (2006); Cooke-Davies(2002); Davis (2013); Jugdev, & Müller, (2005); Luu, Kim, Huynh (2007); Nguyen, Ogunlana & Lan (2004); Shenhar, Levy, Dvir, (1997); Sylvester, Rani & Shaikh (2008); Tatikonda & Rosenthal (2000); de Wit (1988);
As shown in Figure 19, at the start of a job the budget (cost) and schedule (time) are determined in order to achieve the desired quality of the deliverable.

Once the parameters of the Iron Triangle are set, a balance is created (Atkinson, 1999). This means that if the time is to be shorter than initially agreed but the quality maintained, the budget needs to be increased as visualized in the bottom part of Figure 19. The total sum of cost, time and quality remains the same. The total sum depends on what was agreed upon initially. If the agreement or contract leaves room for interpretation this will likely result in a miscommunication on Time, Cost or Quality deliverables. In order for the Iron Triangle to work clear definitions on the deliverables are required.

### 4.3.3. Additions to the Iron Triangle

Many authors* feel that the Iron Triangle presents a too limited picture of the reality and propose additions. Wright (1997) on the other hand proposes a reduction of the Iron Triangle to the two parameters that are of importance for the customer; time and cost. His reduction is often regarded as too minimalistic with an assumption on the delivered quality. Though the reduction can be favorable in time pressured projects such as the millennium projects, the reduction is unrealistic given the demand on quality in common projects. Take for example Defense or infrastructure projects, it is then far more important to deliver then delivering in time or in budget. Often budget and schedule are increased as long as the product is delivered. Only measuring time and cost will then lead to irrelevant performance indicators. A similar observation is made in large construction projects. High quality materials, design or deliverables are part of what a customer wants and is willing to invest time and money in. Leaving out quality is thus not an option.

De Wit (1988) observes, in a survey among 103 development projects in thirty firms, three success criteria: Technical performance [of the delivered project], Cost performance [during construction], Schedule Performance [during construction]. He however separates performance indicators in effectiveness, efficiency and satisfaction. His main argument for this division is as simple as it is true: “A project may be perceived a success one day and a failure the next. Therefore, to think that one can objectively measure the success of a project is an illusion.” (de Wit, 1988). The performance fully depends on the perspective taken. Depending on the deciding perspective, which depends on the situation, the performance measurement has to be adjusted. De Wit has for this purpose created an incasing Project Success Framework.

Atkinson (1999), with regard to previous adjustments to the Iron Triangle from other authors, proposes a Square-Route Framework adding information system, [organizational] benefits and [stakeholder] benefits categories to the Iron Triangle as visualized in Figure 20. His Square-Route additions each measure the resulting effects of a project in various ways, in order to decide on the success of it. Atkinson also refers to the categories as respectively (starting from right upper corner in Figure 20 clockwise) technical strength, indirect benefits and direct benefits of the created system thus indicating what they aim for. Atkinson does however not have specific lists of parameters per category. Most noticeable to this approach is that it focusses on benefits for all the stakeholders. This framework is thus best applicable where the stakeholders benefits are just as valuable as the project performance. Such a situation can be found in public-sector projects where politics dominate and the perceived success is more important than...
the actual performance (de Wit, 1988). The framework is thus not useful for AJS where the projects are delivered based on what the client wants.

Luu, Kim & Huynh (2008) propose nine “major” KPI’s measuring the performance of large (onshore) contractors in Vietnam. Additional to the Iron Triangle parameters Cost and Time are in two accounts of customer satisfaction, a project team rating and the management of respectively quality, change, materials and labor. All the last seven parameters are measured on either a 10- or 5-point Likert mark and filled in by the customer. The performance on these marks is thus greatly dependent on how the client has perceived the construction. Given this large influence of perceived performance it can be said that these parameters are a (multiple) measure of Quality as found in the Iron Triangle. The approach on customer satisfaction is interesting and can be used by AJS in order to measure the satisfaction of ONEgas. This satisfaction can then be included in the Quality assessment.

Sylvester, Rani & Shaikh (2008) use the Project Management Triangle (PMT) in their search for focus and constraints which Oil & Gas Companies and Contractors are prone to satisfy in Malaysia. The PMT uses among Cost, Time and Quality also Scope. Several definitions on quality and Scope are given, in which Quality is often defined as the customer experience whereas Scope is strictly the deliverables or deadlines of the project.

Compared to the Iron Triangle the Quality is in the PMT split in Quality and Scope in order to separate perception and specific deliverables. Similar to the Iron Triangle do the other factors determine the last factor. Sylvester et al. conclude that the oil & gas companies and contractors focus on time, quality and Scope. They are willing to pay for the desired level of each of these. The cost of a project is thus a resulting factor as shown in Figure 21. Sylvester et al. (2008) found the cost to be the resulting factor due to the main focus on high quality products with low maintenance (frequency and cost) and high efficiency of Oil & Gas Companies. The strict contracts and procedures force and motivate the contractors to adapt this focus. The authors note that the Oil & Gas industry may have other foci at other locations and the research is thus not just to be generalized. Their separation of quality and Scope provides a convenient division of measurable and perceived Quality. This can be used for the assessment of the Quality performance of a project.

### 4.3.4. Project Management Triangle and Quality

Though the Iron Triangle is not exclusive, more recent literature does not add any similar important parameters. The reduction of the Iron Triangle as proposed by Wright is deemed unrealistic by this author as well as others in literature. De Wit points out the three measureable categories of factors on a project; effectiveness, efficiency and satisfaction and adds a remark on the perception of success. Atkinson, with regard to previous literature, proposes three additional categories based on received benefits. He does however not have any specific parameters. Luu et al. on the other hand propose nine major KPI’s of which seven fit a quality check. The KPI’s could thus be seen as a more detailed Iron Triangle. Sylvester et al. approach the oil & gas industry with the PMT. This PMT is very comparable to the Iron Triangle whereas Quality is split in quality and Scope. Except for Wright, every author uses parameters similar or exactly like the Iron Triangle as a basis for their research. The only difference is seen in the approaches for the assessment of Quality. Additionally the PMT offers a distinction between Scope and Quality. For the measurement of the performance of projects, the PMT is thus taken as the basic parameters. The PMT with the proposed performance indicators are explained below and shown in Figure 22. The proposed performance indicators are used for the benchmark.

The four major parameters of the Project Management Triangle are Cost, Schedule, Scope and Quality. Cost and Schedule both have three measurements: Estimated value, Changed or adjusted value and Actual value. The estimated value is the initially estimated value for the project. The change or adjusted value is an adjusted estimate based on changes approved by the client. The actual value is the cost or time needed to complete the project.
Cost and Schedule date are fairly easy to retrieve as expenditure is registered in Cost Reports and planning is recorded in CTR Manhour Summaries. These two documents are made per project by dedicated employees. Here “dedicated” means that the function of the employees is to process and register the required data into either a Cost Report or a CTR Manhour Summary. PCR’s are additionally taken into account since they are the only way to make adjustments to either budget or schedule.

Scope is recorded by means of KPI milestones as registered in the ISC. Changes to these milestones are described in the Project Change Request (PCR). In such a PCR the effect on Cost and schedule is also described. Every PCR needs to be approved by the client in order to take effect.

Determining the Quality of a project is a different story. As was described in the previous paragraph, Quality can be measured in different ways, all much depending on what the researcher wants to know. Most authors make a distinction between objectively measurable and perceived Quality. Though determining an actual quality performance would require a study in itself, there are some parameters which could be used. In the case of AJS the objectively measurable parameters could include Non Compliance Reports (NCR), time to close a NCR, the number of missing documents offshore and the hours of rework. The more subjective part of the quality, the customer satisfaction, can be determined by means of a questionnaire in the close out phase of the report.

Figure 22 PMT with Proposed Parameters

1. KPI Milestones
2. Project Change Request (PCR)
3. Estimation
4. PCR value/impact
5. Actuals
6. # Non Compliance Report (NCR)
7. Time to close NCR
8. # Missing documents
9. Hours rework
10. Customer satisfaction
11. Estimation
12. PCR Value/impact
13. Actuals
4.4. Seven Paradoxes of Performance Measurement

Research into the (dis)advantages of performance management has led to a related field of research; the (organizational) effects of performance management. As with performance measurement itself, this field has a large number of contributions. Especially interesting in this case are the perverse effects performance management can have on an organization (de Bruijn, 2002). Such effects could hinder the performance management or even render them fully useless. This needs to be taken into account in order to properly measure and monitor performance.

As shown in chapter 5, AJS has a large number of projects with a total cost below 500K. The Project Management ratio as preferably used by ONEgas is thus likely to be high, compared to international standards, as the hours have a bigger impact on the smaller budget of the project.

Within AJS a number of performance measurement paradoxes are visible. De Bruijn (2002), describes seven paradoxes, displayed in Figure 23. De Bruijn differentiates three groups within an organization: Management, responsible for strategic and long term goals of a company. Professionals, who are tasked with the work on projects, departments, workgroups or similar. The third group is in between, boundary spanners take upon themselves either by function or their own initiative to translate the goals from management into more concrete guidelines for professionals.

4.4.1 Paradox 1 – More Manager Less Effective

The first paradox focuses on performance measurement as a steering tool and as such becoming a separation between management and professionals. When a Manager tries to control the system in detail, professionals are likely to disregard the measurements. Measurements are then performed but will have little meaning.

4.4.2 Paradox 2 – Reward or Punish Performance

Figure 23 Seven paradoxes of Performance Measurement (de Bruijn, 2002)
4.4.3 Paradox 3 - Balance Between Product and Process

In this appraisal can be found at the Team Leads of the one thing aliased at the time span focused on the铁

4.4.4 Paradox 4 - Room for Change

In this case ONEgas is indirectly diverting AJS from what it actually offers this room for an open playing field.

4.4.5 Paradox 5 - Professional versus Managerial Rationality

Here the different approaches of the Manager and professional clash. The Manager seek information in order to account for performance while the professional prefers to see the diversity of his profession displayed. Here lies a major function for the boundary spanner able to bridge the gap between numbers and work done.

4.4.6 Paradox 6 - Only Effective when Limited Meaning

Similar to Paradox Three the second to last paradox aims for a balance between appraisals. When only one form of performance measurement is used there is a strong incentive to play the system and influence the paper performance without actually changing it. Appraisals should thus be based on different indicators. Additionally there should be room for a certain tolerance in performance.

4.4.7 Paradox 7 – Performance Measurement the Game

The relationship between management and professional consists of a playing field that offers room for negotiation on the desires of one and the possibilities of the other. Though performance measurement is based on the idea of steering on performance in order to improve the situation and accordingly the performance, holding on too tight will result in failure as described before. Interaction, variety and dynamics offer this room for an open playing field.
4.4.8. Conclusion Paradoxes

Of the seven paradoxes, four were found applicable to AJS-ONEgas. Managerial control is too tight on professionals, leading to the loss of value of the work done. In addition to this the compensation for performing well has led to an attitude toward the compensation rather than the focus on the product. The balance between product and process is stressed by the conflicting targets on low cost, high quality and low duration. There is however room for change in the current organization.

The AJS management plays an important role in bridging the gap between the client and the professionals. The Team Leads are in the best positions to reward the performance of the professionals. For the last paradox more time is required to make a justified conclusion.

The main point of the seven paradoxes is not to move only into one direction. Performance measurement can help monitor the progress but should not determine it. Accordingly performance measurements need to be put into perspective before they should be acted upon. It is advisable to leave some space for negotiation and always bear circumstances in mind.

4.5. Quality Management

Quality management has made large improvements since right after the Second World War, with the likes of Shewart, Demming and Juran (Emmerik, 2012) setting the stage in Japan for improving and guaranteeing quality of work with the Demming-circle, Pareto-80|20-rule, Big Q and Little Q. It is thus not surprising to see that further techniques such as Six Sigma and Lean manufacturing developed in the same country based on work of the above mentioned authors. Such techniques can provide valuable input for the organization in order to improve the quality of work delivered. These techniques are widely documented and available. Depending on what AJS wants to target to improve its work process the most useful technique can be chosen.

Quality management should definitely be looked into when problems are addressed. The sheer size of the topic requires a separate study to come to a decent analysis and solution to the problems addressed.

4.6. Concluding on Literature Review

After diving into the literature on the subjects of complexity, benchmark(ing), performance measurement and paradoxes of performance measurement, definitions per subject were established. Complexity for example is defined as four points that need to be fulfilled for something to qualify as complex. The definition of benchmarking found in the literature was restricted to match its purpose as a verb. This was necessary due to the large spread of goals and overlap of the literature definition with dedicated fields of research such as Quality Management.

The literature review shows that for the assessment of the AJS project performance, the use of the Project Management Triangle is most appropriate. The PMT proposes indicators on the Cost, Schedule, Scope and Quality. Data on the first three indicators can be found for any project, therefore allowing widespread application of the indicators. De Wit (1988) teaches us that Quality is a subjective indicator and can differ per actor. When measuring the performance it is thus important to measure several factors and put the results into perspective.

From the seven paradoxes, four were applicable to the current situation. The seven paradoxes’ main focus is, not to move solely into one direction. They show that performance measurement can help monitor the progress but should not determine it. Accordingly performance measurements need to be put into perspective before they are acted upon. It is advised to leave space for negotiation and always bear circumstances in mind.

By means of the literature study, the five tertiary question were answered. Numerically ordered:

2.1 “What performance indicators from literature are suitable for AJS projects?”
2.2 “How can the AJS project data provide the required information as required by literature?”
2.3 “How can the AJS performance be influenced according to literature?”
2.4 “How does literature propose to counter the perverse effects of performance measurements on AJS projects?”
3.2 “How can the findings on performance measurement based on literature be interpreted?”

The answers to these questions can be found in paragraph 8.1.2.
AJS Projects

AJS is due to the ISC not allowed to serve anyone else but ONEgas and vice versa when maintenance and modification is concerned. These projects differ from their onshore counterparts due to the weather conditions and supply chain to the location. On the location is only available what is delivered. Detailed planning is thus required in order to be able to do the job.

Even though the cost made by AJS only amounts to roughly 10% of the total project cost, ONEgas pressures AJS to improve its performance (Bajema, 2014). AJS, via Jacobs, requested the creation of a standard benchmarking tool in order to tackle these problems. As a Jacobs intern at AJS, I am expected to analyze the system, stakeholders and respective targets in order to produce a useful benchmarking procedure for AJS projects.

5.1. AJS Project Phases

Every year a large number of projects are started and finished by AJS as assigned by ONEgas. The majority of these projects concern modifications and maintenance, whereas a small part of the projects concern new (parts for) installations on the ONEgas assets (AJS, 2014a). Any of these projects consists of three phases. For some projects AJS is involved earlier on for advice. In those cases a project can, when executed, last four phases.

An adjusted version of the Shell Opportunity Realisation Process (ORP), as is visualized in Figure 24, is used by ONEgas to address the different phases of a Project. First the unadjusted ORP will be discussed and then compared to the adjusted version in order to show what information is forwarded to AJS.

The relevant AJS project phases are Select, Define, Execute and partly Operate due to the extended warranty demanded by the client. Optionally AJS can be called in for an early estimate in the select phase of a project. As indicated in the bottom two rows of Figure 24 the cost estimate and schedule in the assessment phase are only level 1, indicating they are based on aggregated data or educated guesses of the engineers involved. With every higher level the accuracy will be increased as indicated in the bottom left corner of Figure 24.

**Figure 24 Opportunity Realisation Process (ORP) (AJS, 2014c)**
The method defines three decision gates as shown in Figure 24 by the numbered indications in the flow diagram. The decisions made at those gates are the resultants of a comparison of the cost estimated by AJS. The estimated cost of the work thus plays a large role in the decision to proceed.

The first decision gate is at the end of the Assess phase where based on the level 1 schedules and cost estimates a decision is made by ONEgas if the work is to be continued. After this first gate, AJS can be involved to help out with the selection of the appropriate concept. In the Select phase a concept is selected and further detailed on an aggregated scale.

The second decision moment is after detailing the selected concept into a Basis for Design (BfD). The third decision is after finishing the details concluding in a Basic Design Engineering Package (BDEP). This last decision, if approved, starts the Execute phase where the plans are further detailed based on the materials of the suppliers and then the required acquisitions are made.

5.2. AJS Project Process

With every new project the matrix type organization of AJS produces a new project team. The adjusted version of the ORP is dubbed ONEgas ISC Project Management Framework and is pictured in Figure 25. The actions and deliverables are put below the adjusted ORP flow. The actions and deliverables are colored yellow with red when ONEgas is responsible. AJS parts are colored blue and white. Actions or deliverables with combined responsibilities are colored yellow with blue.

![Adjusted ORP, ONEgas ISC PMF. (ONEgas, 2013b)](image)

Additionally two red with white squares mark the unchangeable state of the plans when a decision (yellow triangle) is taken. The blue triangles lettered A to E are Quality checks. These are done by AJS on the work of the preceding (partial) phase.

Any project starts with a Basis for Design (BfD). This is a concept of the structure/part and the associated cost and schedule. The BfD will be detailed into a Basic Design Engineering Package (BDEP) project plan where the estimate variances are reduced to a variance of $+15\%$ en $-10\%$ of the total cost. The new estimates will differ from the previous ones as more data has come available, a Request for Variation is thus needed in order to establish a BDEP.
Once approved, the Contractor Target Cost Estimate (CTCE) is made by AJS for the BDEP and Execution phase with an accuracy of respectively level 3 and 2. In this phase possible suppliers will be contacted for price and deliver time estimates. The engineering plans will be further detailed with the data from the suppliers. This can lead for example to a different pump as the original estimated pump is replaced by a newer version. The engineering plans need to be adjusted to facilitate the new pump.

Since the plans and drawings are now further detailed, estimates are revised based on the new information. For AJS to move to the Execute phase, ONEgas needs to approve the changes. Consequently ONEgas will then apply for a request of variation to AJS. Without this request work on the execution phase is not started.

The Execution phase consists of minor changes to the schedule and drawings based on the latest information on available supply chain capacity. Once all details on the drawings are finished the work packing can start. Work packing is seldom found in onshore projects as they have plenty of space to gather their supplies. Offshore this is very different. As explained in chapter 0,

Once a project phase is initiated, Activity Allowance (AA) is assigned to AJS. Activity Allowance is project specific depending on the Scope, available data and risk. Often it constitutes up to 10% of the estimated cost and is then included in the estimation (McGoun, 2014a). The AA is to be used in order to cover Scope development and other uncertainties having a high possibility of occurrence (AJS, 2014c). AA is part of the AJS budget and requires no approval by the client to be spent.

If during a project phase more money or hours are needed than estimated, additional resources can be requested by issuing a PCR to ONEgas. The cause of the change of required resources is categorized in either External or Internal. This last category houses two main causes; the first can directly be related to AJS actions and could have been circumvented. This is paid for out of the AA. The second main cause concerns the transfer of (superfluous) cost and or hours from one phase to another. The External category on the other hand, is used for all changes due to the client or unpredictable circumstances such as the weather or effects of other projects. The client can however also decide to postpone or even cancel the whole project when costs have grown above the acceptable level. AJS is kept in the dark by ONEgas what this level is for a project.

5.3. AJS Project Categories

The projects are in compliance with AJS policy divided in three categories: Maintenance, Modifications and Capital projects. Currently there are twenty capital project and fourteen flow line projects.

5.3.1. Project Phase Categories

In accordance with the ONEgas ISC Project Management framework, AJS projects can be categorized based on the phase they are currently in or of which data is available. Within AJS, the phases are named after the final deliverable. The Select phase is thus Basis for Design (BfD) or, on occasion, feasibility study. The Define phase is spoken of as BDEP or Concept. The Execution phase is also referred to as the Detailed Design (DD). The Operate phase is only mentioned as Close Out.

5.3.2. Jacobs Cost Categories

Currently no distinction is made between large or small projects whereas this is important when comparing projects due to overhead cost. Analysis has shown that small projects for example will have a large Project Management share whereas larger projects will have a smaller share as the amount of Discipline hours increases. Similar impact can be seen when the transportation cost is compared to the total cost of a project. These impacts need to be taken into account when comparing projects. For example when a large group of projects without distinction is taken, analysis shows that averages are increasingly meaningless due to the large diversity of results.
Within Jacobs a solution was found to an identical problem when comparing the engineering hours among projects (Sammelius, 2014). The problem occurred when a client (an oil company) claimed that the engineering hour ratio of Jacobs was bad on some projects compared to average ratio as published by IPA. Given the large number of mega projects incorporated in IPA’s database the ratio logically tends to be lower than smaller projects. An appropriate comparison is thus required. In this case projects were split in groups of values up to 500K, 1000K, 2000K, 4000K and 10,000K. The overall engineering cost per Total Installed Cost (TIC) category is shown in Figure 26. When looking at the graph in Figure 26 it is clear that smaller projects require a larger percentage Project Management compared to larger projects. When comparing these numbers, it should be taken into account that Jacobs only works on the Engineering and Project Management on a job. It outsources the construction and related management such as work packing.

The cost categorization is applied because a separation in different categories has proven to result in different characteristics per category. The Jacobs cost categorization is used to open the possibility of comparing AJS and Jacobs project data. This would allow AJS to perform an external benchmark.

An evaluation of twenty-five AJS projects shows that most projects are in the 500K range as shown in Figure 27. Where K is 1000 and 500K then equals 500,000. One can thus expect a high average Project management over total cost ratio when all projects are averaged. Comparing against IPA standards with a large portion of mega projects (> 10,000K) will likely show large differences. A list of project numbers and their categories are included in AJS Data Analysis.

5.4. Available Data of AJS Projects

The recorded data was available without limitations for projects dating back to June 2012. The recorded data of projects before June 2012 is currently unavailable. The data is retrieved from the network drive of AJS or requested from the responsible employee. Below it is explained what kind of data is available. Most important are the Cost Reports and CTR Manhour Summaries as they hold most of the non-engineering information on a project. This information is crucial when a management summary is desired because it gives an overview of the most basic information of a project: Cost, Scope and Schedule. The Quality of the work can only partially be derived from these documents as there is no indication of the process and agreements behind this information. A separate procedure should thus be added to include a measurement of Quality.

Non-engineering meaning here all the data that is not considered an engineering drawing. As Engineering drawings are very specific and the details differ per project they are not taken into account for the comparison of projects. Such a comparison can be made but the drawings will have to be generalized. The generalization of such drawings requires specific knowledge of the engineering task and used software.

5.4.1 Cost Report

The Cost Report is an Excel workbook with twelve to thirteen sheets. A Cost Report is created and maintained by a Cost Engineer. It holds all financial information considering the project and is used as a financial overview by the Project Engineer and the client. The first sheet provides basic information such as project name, description, start date, Project Engineer, Client Representative and Cost Engineer.
relevant sheets are the CP Detail Summary with the cost split per cost category, the PCR register and PCR calc. The latter two provide information on how the costs associated with a PCR are split among cost categories.

The Cost Report greatly depends on the value of engineering time and material value which may vary in time due to scarcity, new techniques or inflation. Over larger periods of time (more than 5 years) at least inflation should be taken into account.

Project Cost Reports are updated continuously leading up to a monthly version. The Cost Report of the current month is thus always a live document until the document of the next month is started. The monthly Cost Reports document all cost developments up to and of that specific month.

A project with a two year duration has twenty-four monthly Cost Reports and a Final Cost Report. The Final Cost Report documents the cost developments from start to finish. The monthly versions give a good insight of the current status of the project but cannot possible incorporate all future costs because some changes are not foreseen. When the monthly Cost Reports are used for a comparison of projects, this comparison may prove incorrect with future developments in a project. For example the categorization of a project by cost may change due to an increase in cost either by budget growth or budget overrun in the future. Given the unchangeable state of the Final Cost Report this risk does not exist for the Final Cost Report.

5.4.2. CTR Manhour Summary

The CTR Manhour Summary is a list of all the booked hours per bookings code per project phase of a project. It is a pdf export of the Primavera file showing the data spread over thirteen headings. It is created and maintained every two weeks by a Planner for the Project Engineer and client to provide an insight into the amount of spend hours and still required time to finish. The main header is displayed in Figure 28. The first two columns cover the ID numbers and activity names offering a description of what kind of hours were booked. Of the remaining columns most basic are the CTCE, Approved Budget, % complete and Actual hrs Expended. In between one can find the calculated values on latest budget, earned hours, remaining work and forecasted hours needed to complete the job at the current pace. ID’s are created according to a procedure, creating a unique code from which project number, area, phase and function can be distinguished. The CTR Manhour Summary data can also be copied to an Excel file and saved as such. The actual and budget amount of hours are taken by the Planner from a Timenet export.

The latest CTR Manhour Summary is put onto the internal ONEgas network for everyone with permission to access. Later trending of the project data is thus not possible as only the most recent version is available. Similar to the Cost Reports it is advised to benchmark only with the finalized data of a project because these files are the only files with all the changes included.

5.4.3. Timenet Export

Similar to the CTR Manhour Summary, the Timenet export shows budget and actuals hours. The Timenet export consists of the data in the time writing system, Timenet. Budget and actuals are related to their booking code as used by the Planner. The advantage of using a Timenet export over a CTR Manhour Summary is the large amount of projects which can be accessed at once. The disadvantage is the lack of estimated hours. The original estimate is not included in the Timenet export. Importing the data will thus take longer but once imported all projects of the past five years are accounted for.

5.4.4. Non Compliance Reports (NCR)

Non Compliance Reports are filed when construction workers offshore have a question, addition or notion on an incorrect or missing part during construction. They are filed by the offshore construction
workers. One would expect that the number of NCR's would give an indication of the mistakes or incorrect parts or procedures on a project. As such it could be an indicator of quality of the work on a project. Analysis has shown that NCRs consist of an explanation with little categorization but no estimated value. The exact effect or relation to the value of a PCR can therefore not be retrieved.

A NCR is currently also used as a way to air dissatisfaction. For example, instead of ten NCR’s with minor adjustments, one NCR is made with the complaint about continuous minor adjustments. The information on the exact adjustments, number and time are thus lost. The number of NCR's thus tells little about how well the engineering was done. The NCRs can thus only serve to recap at a later stage when a NCR was written and what it says. Their use could be increased when they are linked to PCR's or have values added to them in order to see how much extra time or cost was required to solve the problem. When done so, the NCRs would add much more relevant information to the project process. In their current state they are only an administrative action.

5.4.5. Project Change Requests (PCR)

The values and cost split of PCRs are included in the Cost Report. The original (paper) PCRs are saved digitally on the network drive as part of the paper trail. Since the value and cost split can be retrieved from the Cost Report the PCR document is not useful to the benchmark. In case further detail is necessary the PCR document can be used. It is noted that some details of the PCR are neglected in the registration. Examples of these details are the exact submission and approval dates and proper elaboration on the applicable change. The registration of the examples has improved when comparing projects prior 2012 to post 2012. In rare cases the details are however still left out without any registered argument.

The addition of the link of the PCRs with NCRs, when applicable, would increase the transparency of the process. This addition can be realized by a minor additions of the NCR numbers, which affected the PCR, in the description of the PCR.

5.5. Concluding on AJS Projects

The wind, limited capacity, high transportation cost and impact of missing parts is already taken into account during the design and planning of the construction. This means AJS has more Project Management due to additional tasks such as work packing. Offshore projects will thus always show a high amount of Project Management hours compared to onshore projects.

The Current Cost Reports and CTR Manhour Summaries provide much information on the (development of) cost, schedule and Scope. This is however only applicable to the newer reports which have been filled precisely with relevant information. Prior to 2012 this information is less accurate and sometimes even incomplete. The date, subject or explanation can be missing or is unclear. In the newer reports this is rare, can however still occur. This detail might not seem relevant but is very important for the more in-depth look at the data.

When, for example, determining the reaction time after a certain file has been submitted for approval, the submission date and approval date are crucial information. When either one or even both dates are missing in the reports, an analysis of the reaction time cannot be performed. Even worse is registering any date, as this will sketch an incorrect image of the situation while wasting precious time.

The information of the Cost Reports and CTR Manhour Summaries is crucial when a management summary is desired because it gives an overview of the most basic information of a project: Cost, Scope and Schedule. It is thus key that these documents are continued for future projects in order to have an overview of the project. When the NCRs are filled in with more accuracy they may be used to determine the Quality of a project. Currently the Quality of the work can only partially be derived from the documents, as there is no indication of the link with the project process or resulting changes.

Answers to the following tertiary questions are found in this chapter and answered in chapter 8:

1.1 "What are the general characteristics of AJS Projects?" is thus:

3.1 "How can the findings on current AJS project performance be interpreted?"
CH 6. **AJS Benchmark Requirements**

AJS prefers a benchmarking method which is simplistic and pragmatic. The time spent to perform the benchmark must be minimal, preferably none at all. If any actions are required they are to be integrated in the AJS project processes. Admittedly, any extra work cannot be done without extra time. Creating the benchmark must therefore not become a lengthy task. Additionally, the internal workings of the benchmark must be clearly elaborated upon for possible future adjustment (Bassie, 2014a; McGoun, 2014c). The five requirements are listed in Figure 29.

### 6.1. Simplistic

The first requirement is that the benchmark should be easy to understand. Much data is involved in producing the benchmark and in order for it to be simplistic, the complexity needs to be reduced. From literature it was found in chapter 6 that complexity is based on four points. Reducing complexity is thus achieved by decreasing each of the four points in Figure 30.

First of all, the **number of elements**, concerns the amount of visual representations shown to the user. This can be a button, colored area or graph. For each of them the principle of “less is more” is applicable. Their number is thus restricted to a minimum. The buttons are limited to “Include Project”, “Reset” and “Remove Specific Project” button. Coloring is done according to the current format of Cost Reports and CTR Manhour Summaries. Graphs are only used to visualize the final numbers.

The second point, **differentiation of project elements**, is taken as the different kind of actions to be performed for reaching the results. In the most general sense the necessary actions are restricted to clicking with the mouse on either a button or a sheet and scrolling. On a more detailed level different buttons need to be clicked and the added projects need to be selected from dropdown menus.

The **interdependency of the project elements**, the third point, targets the relations between the different parts of the benchmark. In this case the four information sheets on which the data is copied. This data is then used in the calculations. The information sheets are not related or connected in any way. In order to retrieve the right information every project number is set atop of the retrieved data.

The **uncertainty of project elements** is interpreted as the chance that the user might misunderstand or incorrectly use the benchmark. This chance is minimalized by the low number of actions and a comprehensive manual. The step-by-step manual list explains what to do and how to do so. A screenshot of the manual can be found in Appendix G: Excel Manual.

### 6.2. Pragmatic

The benchmark should be pragmatic in its use. It is assumed that it will only be used by AJS employees and thus a basic knowledge is available. The basic knowledge of an AJS employee is in this case interpreted as knowing what documents are called, where they are found and what the abbreviations such as CTCE (Contractor Target Cost Estimate), CTR (Cost Time Resource) or PCR (Project Change Request) exactly mean.

Furthermore, a basic knowledge of Excel is assumed. Similarly to the AJS basic knowledge, Excel basic knowledge must be read as knowing how Excel is started and that formulas change cell values. For the use of the benchmark no more knowledge is necessary. In order to change the benchmark, specific knowledge on VBA programming is required. This is detailed in paragraph 6.5.
6.2.1. Number of Elements

In order to make the use of the benchmark straightforward, the complexity of the activities is reduced. The first point, number of elements, was interpreted as the minimization of used data, data inputs and activities. As previously discussed in chapter 6 the minimal needed information for an AJS benchmark is defined as Cost, Time, Scope and Quality. The minimal required data was narrowed down to the Cost Report and CTR Manhour Summary. For the first the Estimated, Transferred, PCR and Actual costs were used along with the PCR values as they are present in the same Cost Report file. The Estimated, Transferred, PCR and Actual Manhours are copied from the CTR Manhour Summary file. For both the Cost Report and CTR Manhour Summary four columns were found to be sufficient to provide the required information. Additionally extra information on PCR's is retrieved from the Cost Report to categorize the changes on a project. The number of input data was limited to two files.

The minimal number of actions is measured in the number of clicks needed to get from the clean benchmark to the benchmarking results. For the import of data this can be as little as four clicks with an additional click per Cost Report when the multi select is used. Otherwise it is four clicks per addition of project data. The exact actions are shown in Appendix G: Excel Manual. The minimal number of clicks per input is listed in Table 2.

6.2.2. Differentiation

The second point, differentiation of project elements, was explained as the reduction of different data formats. The Cost Report is a monthly Excel document with twelve sheets per workbook. Each project has its own Excel workbook and is named after the project code and short description. The CTR Manhour Summaries are usually exported in pdf format from Primavera. Primavera is advanced software for planning and Project Management (Primaned, 2014). The proper use of Primavera requires training and experience (van Wijlen, 2014). During the research it was found that the data in Primavera cannot be exported to Excel. It can however be saved in Excel by simply selecting the data in Primavera and copy-pasting in Excel. Both the data in the Cost Report and CTR Manhour Summary can thus be accessed in Excel, reducing the differentiation in file formats to a single format. The reduction of the data types simultaneously results in the use of only one, widely known, software: Microsoft Excel. This then reduces the differentiation to other project related work where Excel is also used.

6.2.3. Interdependency

The interdependency of project elements, the third point, was read as the reduction of relations between data in order to reduce correlations. This serves two purposes: firstly the reduction of relations cleanses the data of double information sources. Secondly the reduction of relations simplifies the effect of changes and makes the effect thus easier to understand. In order to reduce the interdependency of project elements one has to ensure that the input data is of the most basic form. This means that there is no other registered document that holds the same information before the used document. “Registered” indicates the availability of the data to the rest of the company. Personal documents are thus not taken into account.

6.2.4. Uncertainty

The uncertainty of project elements is interpreted as the chance of having an incorrect element in place. The research thus focused on eliminating all incorrect or superfluous data. This meant specifically that ‘living’ documents were not taken into account for the analysis. Given the monthly updates of Cost Reports only the reports of the previous month could be taken into the analysis as the current month proved to be a ‘living’ document. The Manhour Summary had to be requested as they are normally not saved in Excel format. The documents are updated every two weeks in pdf, showing (part of) the total planning and the project progresses. Both the Cost Report and the Manhour Summary are incomplete documents until the project is finished. They can thus only be compared to projects at exactly the same time relative to the project. The developments in a project can however change the project duration and total cost. A comparison of live data may at the time seem correct but unexpected changes can alter the project duration and cost in such a way that the compared projects differ too much to be compared. Any previous comparison is then rendered useless.

As every project has a different duration, comparing the living documents to previous projects at a similar time is possible but can give an incorrect view. To prevent any uncertainty in the data only the finalized project data is compared.
6.3. Minimal Time

Though very important, the benchmarking of projects is an additional task and should affect the ordinary course of business as little as possible (McGoun, 2014d). The benchmarking process should thus take as little time as possible. Even though the clicks are minimized and the data limited to two workbooks, this still involves four Excel sheets and several thousands of rows of data. The limited number of clicks can still result in long computing times where the affected PC is unavailable for other work. The time needed for the benchmark is thus measured in seconds from an empty benchmark to the benchmarking results. In Table 2 the required time is listed per input. The fastest times were set on a Z620 HP workstation PC with an Intel Xeon E5-2620 v2 processor and 16GB of RAM. The times to result however are only a couple of seconds faster than on the HP Thin Clients which are commonly used by AJS. The amount of time and effort can help decide who will perform the benchmark.

6.4. Integrated in the Work Process

The benchmark should be integrated in the standard work process in order to minimize effort and maximize value. As can be seen from Table 2 the time per project can vary between 0.2 and 15 seconds. The total time in tests varied between 15 seconds and 2 minutes (with a dedicated PC) depending on the number of projects. When more than five projects are selected the processing time increase accordingly. Given the fact that the PC cannot be used for other tasks during the importing of data, the importing of larger data sets should be planned carefully or done on a separate PC. Depending on the day of the week a flex desk PC may be available to perform the import. This would allow importing and working simultaneously as another PC can be dedicated to the import.

Given the fact that it concerns either a Cost Report or a CTR Manhour Summary the respective responsible employee could perform the task. This would thus mean that a Cost Engineer and Planner get the additional task of adding the final Cost Report or Final CTR Summary to the benchmark. Due to the simplistic set-up of actions any employee of AJS or ONEgas with access to the files could perform the actions. As mentioned in paragraph 6.2.4 only finished reports are included into the benchmark. The Cost Report and CTR Manhour Summary are closed as the last part of the close out process in order to incorporate everything. It is thus advisable to incorporate the benchmark in this process after all the reports have been filed.

6.5. Clear Elaboration

In order to adjust the benchmark to possible future changes or new insights, the current work is elaborated upon for future enhancements by others. Along with this report detailing the search for appropriate and suitable performance indicators for the benchmark, also the created VBA code in Excel is explained, per part, in the code itself. This way, losing the explanation when it is separated from the code cannot occur. A part of code with elaboration is displayed in Figure 31. The elaboration is colored green and always starts with an apostrophe (‘). Alongside that space are used when opening up a new function such as for(), if() or with(). Functions are colored blue and any code in the function is put one tab to the right. This thus allows future improvement and additions to the code.

Figure 31 Example of VBA Code From The AJS Benchmark With Explanation

<table>
<thead>
<tr>
<th>Input</th>
<th>Clicks to results [click]</th>
<th>Time to results [sec]</th>
<th>Number of Imported projects</th>
<th>Import Time per Project [sec]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost Report</td>
<td>4</td>
<td>25</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>CTR Summary</td>
<td>4</td>
<td>15</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>multi select [3] CTR Summary</td>
<td>7</td>
<td>17</td>
<td>3</td>
<td>5.6</td>
</tr>
<tr>
<td>[limited] Timenet Dump</td>
<td>4</td>
<td>82</td>
<td>139</td>
<td>0.6</td>
</tr>
<tr>
<td>[full] Timenet Dump</td>
<td>4</td>
<td>117</td>
<td>676</td>
<td>0.2</td>
</tr>
</tbody>
</table>
CH 7. **Resulting AJS Benchmark**

An implementation plan is offered in this chapter in order to ensure a proper roll out and use of the benchmark. The plan mitigates the previously found effects of performance management and benchmarking. The scientific literature was used to flag common, or likely to occur, effects of performance measurement and benchmarking. This is then combined with the actor analysis in order to create a suitable and effective Implementation Plan for the benchmark.

The purpose of the benchmark was to provide an argument in the discussion around the AJS performance and whether or not it is increasing. A benchmark is appropriate as it concerns a comparison of AJS projects. The shortcomings and other comments on benchmarking are discussed in the paragraph 8.3 in the next chapter. This chapter elaborates on the results, development, advantage and use, step-by-step, of the created Benchmark tool. Given the general applicability of the Project Management Triangle, as elaborated upon in paragraph 4.3.4, the Cost, Schedule, Scope and Quality are used as main indicators for the performance of an AJS project.

**7.1. AJS Project Analysis with use of the Benchmark Tool**

An analysis of completed AJS projects since 2009 has resulted in the graphs and figures below. The more detailed figures can be found in Appendix B: AJS Data Analysis. Given the changing state of currently ongoing projects only finished projects were taken into account. The previous twenty-seven projects were then reduced to fifteen.

**7.1.1. Projects per Cost Category**

The spread of the fifteen selected projects over the cost categories is shown in Figure 32 in Blue. It clearly shows a larger amount of small projects. It can thus be assumed that these projects influence the average when looking at Project Management cost as they have a larger portion of Project Management cost. The number of project with an actual over CTCE > 100% are mapped in Green. This shows the number of projects where the actual cost is more than the estimated cost. These project have experienced a budget growth and/or possible an overrun. In Red the number of projects of which the actuals are larger than the estimate plus changes and transfers.

**7.1.2. Budget Growth**

Budget growth is the extension of the budget due to unforeseen circumstances or client desires. This can range from change in function to an additional function required of the planned construction. What they all have in common is the approval of the client. Without the approval of the client it is budget overrun. With the approval of the client it is called budget growth. Given the average number of changes to a project, per paragraph 1.2, it is important to register the increase in budget due to approved changes. This way budget overrun and budget growth can be separated. This separation can also been seen in Figure 32 where the Green indicates the number of projects which needed more than the estimated budget. The Red then indicates the number of projects which, including changes, still have exceeded the budget. The difference between Red and Green shows the amount of projects from which the client approved all the changes. This is important as the increase in budget thus consists of a Scope change. The original estimate could thus not have been right as the scope changed later on. Analysis of the changes in
the fifteen projects has shown an average 22% budget growth. On average a project will thus cost estimated due to changes by ONEgas.

### 7.1.3. Estimates vs. Actuals

Figure 33 shows the difference in actual cost (Actuals) divided by the estimated cost (CTCE) on the left. On the right the Actuals divided by the sum of CTCE, transfers and changes (PCR). This sum is to adjust for developments during the project, either changes to the Scope (PCR) or underestimations (transfers). As was mentioned before in paragraph 1.2, PCR’s are the only method to change Scope and need permission of ONEgas. The PCR value thus consists of approved changes, which have likely not been taken into account in the estimation.

The highest score of a project in the dataset is shown as Outlier high. Max then shows the bandwidth between the second highest and the median. The Median represents the middle number in the data set. Instead of the median it would be more useful to use mode, which indicates the most reoccurring number. Due to the low amount of projects every value is unique. This will lead to an loss of detail in the data.

Outlier low and Min depict respectively the lowest score in the dataset and the distance between it and the median. In Figure 33 and Figure 34 the median is shown instead of the average because the impact of the outlier high on the average is too large. This is due to the large difference between the Outliers.

When the changes are taken into account (difference between left and right in Figure 33) a drastic reduction in Max and Average values can be observed.

It can also be lower when the budget changes were estimated too high. It can be concluded that there are many or large Scope changes between the estimate and the delivered project.

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**Figure 33 Cost Growth/Shrink on AJS Projects**

Many project Scope changes may result in a larger Project Management share as elaborated upon in paragraph 1.2. Consequently to the analysis of the total cost, the ratio Project Management cost over the sum of Engineering (Eng.), Construction (Constr.) and Close out cost was calculated. The execution cost is the summed value of all the cost made in the Execution phase. The Project Management costs are limited to the Project Management cost made in the Execution phase.

Given the likely difference in Project Management ratios, as discussed in paragraph 5.3, a separation of the projects in cost categories is preferable to effectively show a difference between categories. Since there are only fifteen projects, the division of projects in cost categories resulted in too little projects per category. The graphs as shown in Figure 33 and Figure 34 require at least five separate measurement points and preferable more.
Only the 500K category has five different projects, as can be seen in Figure 32. Of these five projects only one has an execution phase. None of the cost categories thus has sufficient projects to, when separated, make a statistical sound conclusion. The graph for all combined cost categories (Figure 34) is thus the only statistical substantiated graph possible. The previously described effects of the project size on the Project Management ratio can consequently not been allocated per cost category. The difference between the estimated median and the actual median in Figure 34 is only 1.2% while the average shows a decrease of 3.4%! This means that on average Project Management costs less than estimated. The median however tells us that on most projects there is a slight increase in Project Management hours. This increase has most likely to do with the applied changes.

It can however be noted that the median, nor the average for that matter, are not at all similar to the values as found in the analysis of Jacobs projects (Figure 26, p33). This most likely due to the cost of materials that are taken into account in AJS projects whereas they are not included with Jacobs. When the AJS analysis is corrected for these values and thus limited to the detailed design phase, the following graphs in Figure 35 are produced.

To put things into perspective: Jacobs had a Project Management ratio between 38% and 19% depending on the size of a project. The overall average of these values is 27%.
of projects the cost category distinction cannot be made for AJS. As can be concluded from paragraph 3.5.5 (p18), only increasing the Project Management ratio by a third instead of triple the amount.

7.2. Development of the Benchmark Tool

At the start of the study on the benchmarking of AJS projects a large amount of information was available. In order to use the data properly the situation at AJS was studied and the data was indexed according to its use for AJS. At the same time scientific literature was consulted on a robust (set of) performance indicators. The indexed data was then selected based on the insights from the scientific literature. The selection procedure is visualized by means of a flowchart in Appendix C. This selection eliminated superfluous data. At that point it became clear that all important file can be saved in Excel format. This common format allows more advanced approaches to the extraction of data from the files.

After the major selection the remaining data still covered five Excel sheets with a total of 4,500 cells. A second, more in depth, selection round was thus required. The data was reviewed in detail selecting only crucial information and dividing the rest into not important or nice to have based on the literature review findings. The amount of crucial data was narrowed down to an average of 1,250 cells per project spread over two excel files and a total of five sheets. The selection procedure of crucial data is visualized by means of a flowchart in Appendix C.

Including the data in a comparison proved to be time consuming and complex as only specific parts were needed. In addition, due to now and then occurrence of copy mistakes, formulas had to be fool proofed. This again was a time consuming task. At this time the addition of a project to the comparison could take from half an hour up to a day depending on how precise the data was handled. This required an understanding of what data was to be found in what file at which sheet in order to manually copy-paste the data. This manual process is very sensitive to mistakes as it is depends on the precision of the work.

Given the uniformity of the task among project data, the data is often found in the same location, and the required precision, the task was automated. As all the data is available in Excel files, the automation was realized by writing VBA code and linking it to a button in the Excel sheet. The proper use of the VBA was studied in order to produce an efficient and effective composition. Every required step for reaching the benchmarking results is, where possible, automated. This automate process is visualized in Appendix D.

It is now possible to retrieve the data on cost or the data on hours per project with one click on a button and selection of the respective Cost Report or CTR Manhour Summary. The executed VBA code will perform all the copy-paste tasks. In order to speed up the retrieval of data, multi-select was added. The multi-select option automatically enables when multiple consecutive excel files are selected.

During testing of the code it was found that the Cost Reports differed on small aspects although they are based on one and the same format. These slight differences in Cost Reports caused some irregularities which the VBA could not process and consequently produced an error. In order to permanently solve these kind of errors, the code was adjusted to find these specific differences and handle it appropriately. A good example is the inclusion of an additional column in some of the Cost Reports. This additional column led to copying the wrong data as it had also moved. The VBA code is adjusted to recognize this additional column and automatically take this into account when copying the data.

The above description of the VBA code may let it seem simple. The process of writing, testing, correcting, testing, correcting, testing and so on, before the final version was fully functioning, was very time consuming.
7.3. AJS Benchmark Tool Advantage

With the insights gained during this study a benchmark was made according to the requirements of AJS: Simplistic, Pragmatic, Minimal time, Integrated in the process and Clear elaboration. They are combined with a literature study on the subjects of complexity, performance measurement and benchmarking in order to effectively meet the requirements and make it scientifically substantiated. These requirements are explained in detail in the previous chapter together with a description of how they are met. The literature study is elaborated upon in chapter 4. The advantage in the combined approach is found in the use of existing methods found in the literature review.

AJS has a large amount of data available, often an Excel file. This data can be used without (much) modification depending on the date it was published. The actions to be performed to retrieve the appropriate data from an Excel file are limited and simple. Performing a benchmark can effectively be done by anyone within AJS or ONEgas.

7.4. Benchmarking Tool Steps

In order to use the created benchmark properly a number of steps need to be performed. The exact benchmarking process is detailed with pictures in Appendix G: Excel Manual. Below different steps of data preparation, use and result use are elaborated upon.

The benchmark tool can only be applied to finished projects because the project data will not change anymore. The benchmarking is always done after a project has finished and the corresponding data is finalized. The Cost Engineer can add the finalized Cost Report to the benchmark. Similarly the Planner can include the finalized CTR Manhour Summary in the benchmark.

7.4.1. Data Preparation

The benchmark is fully dependent on the data input. Truly a “garbage in = garbage out” situation. It is thus crucial to verify whether the input is correct and correctly placed. The benchmark will not have any trouble with incorrect numbers as it does not check if they are correct, this will however dilute the results. All the data required is currently registered in the Cost Reports and CTR Manhour Summaries. In order to perform a proper benchmark in the future these documents need to be continued.

It is advised to take the final documents of a project because these documents include all the changes in any of the four indicators of the Project Management Triangle: Cost, Schedule, Scope and Quality. Taking documents from an ongoing project may result in incorrect comparisons and thus a false image of the performance of a project.

The Benchmark will not work if the data is of a different format. To circumvent any problems the standard format from the current Cost Reports and CTR Summaries is used. These formats are displayed in Appendix C and Appendix F.

The CTR Manhour Summary is normally exported in PDF and should to be copied into an Excel file to be able to use it. The exact same data as in the PDF needs to be copied. Then there is also the possibility of using the Timenet dump. This requires an Excel export of Timenet with ten columns and up to 20,000 rows (current limit of Excel file). The specific order and location of the data is shown in Appendix E: Excel Format Cost Report and Appendix F: Excel Format CTR Manhour Summary.

7.4.2. Use of the Benchmark Tool

As discussed in the previous chapter, the time to use and effort to make are reduced to a minimum. The benchmark is constructed in a way that any employee with access to the needed files can perform the actions. The process can however still take several minutes of computing time. Given the restriction to only include finished projects it is recommended to have the benchmark added as a final task in the close out phase as this is the latest phase in which AJS is involved in a project. The Close Out phase is visualized in Figure 36. Benchmarking will be one of the last actions in the close out process.
As mentioned before in paragraph 5.4 the actual process of adding the new project data to the benchmark is performed by the respective cost engineer and planner of the project. The new project data can be derived from the current Cost Report and CTR Manhour Summary.

### 7.4.3. Results of the Benchmark

The results show a cost performance or schedule performance based on the project data. The resulting ratios are combined in either boxplot graphs or line graphs in order to visualize the ratios and put them in perspective. It should be noted that the graphs only show a comparison of the included and selected projects. The performance of a project is a fixed number and displayed in comparison with the other projects. The results do not show any “good” or “bad” performance. This subjective value can only be placed by taking the performance and interpret them together with the project process. A project may for example perform less than its peers but, considering the number of changes to the scope, actually have done well. Interpretation is thus the key to the use of the performance figures from the benchmark.

### 7.5. Validation & Verification of AJS Benchmark Tool

An important part of the creation of the benchmark, given its vast amount of calculations, is the validation and verification of the calculations and results. Validation concerns whether the benchmark shows the results it is intended to show. The verification on the other hand is a sanity check on the calculations used. The benchmark relies on automatic retrieval of the required data which are then processed by predefined calculations into performance scores and then graphically displayed. From selecting the file up to the interpretation of the graphs the benchmark does everything. It is then crucial to have valid and verified calculations.

#### 7.5.1. Validation

The validation of the benchmark has been done by means of interviews within AJS. This way it has been ensured that a performance actually shows what was supposed to be measured. From a scientific perspective this may not be a perfect validation as AJS is asked to approve a measurement as used by AJS. This method can be faulty to begin with. Considering that Jacobs uses a similar method the validation was the maximum that could be accomplished in this timeframe.

The ultimate validation would be the use of the method in other benchmarking procedures, preferably even in sectors other than offshore oil and gas. Given the business orientation and time limitations this was not possible.

#### 7.5.2. Verification

The verification is essential in order to determine whether the information processed is correct. The verification is done by means of testing on various project data. The different projects can show slight differences due to the preferences of the Cost Engineer. The correct data needs to be retrieved and processed properly. The benchmark was tested with 27 projects on multiple occasions. It then turned out that in combined projects, the sheets are named differently and the static code cannot deal with this and consequently gives an error. In order to counter this error a standard format has been set for the input document.
7.6. Concluding on AJS Benchmark

The created benchmark successfully deals, with help of the literature, with the set requirements. The performed literature study in combination with the available data has led to a semi-automatic benchmark in Excel. The tasks are automated by using VBA code. This allowed for reducing the tasks to clicking a button and selecting the required files.

Due to the small amount of projects the available data is not sufficient to give a statistical sound conclusion. It is also noted that there are extreme values which affect the average values. The figures are thus based on all fifteen projects.

Now that the combination of theory and practice has been made, a final answer can be given to the following research questions:

4.1 "What AJS project performance indicators can objectively be compared?"
4.2 "What tasks need to be performed in order to derive the AJS project performance indicators from the available AJS project data?"
4.3 "What purpose can the AJS benchmark serve AJS?"
4.4 "How can the AJS benchmark best be implemented?"

The answer can be found in 8.1.4. In addition to answering the questions fifteen project were analyzed. The analysis found that there is an average budget growth of 22%.
CH 8. Conclusion, Recommendations and Future Research

This study has developed a benchmark appliance after careful analysis of literature on the subjects of performance measurement, success factors and benchmarking. The leading research question in this study was:

*How can the performance of AJS’ complex engineering construction projects involving maintenance and modifications of gas assets in the North Sea be monitored and controlled?*

The Research question was supported by various sub questions as specified in chapter 2. The search for answers has led to an extensive literature study and an analysis of AJS projects. The findings of the literature study were then appropriately transposed to AJS and induced the creation of a suitable benchmark appliance for AJS projects. This benchmark has gone through the steps of verification and validation based on interviews and testing.

This final chapter is divided into five sections dedicated to respectively the Conclusions, Recommendation, Reflection on the Research, Future Research and the Scientific Contribution.

8.1. Conclusions on the Research

Below the conclusions are given in order of appearance in the report. Consecutively with the conclusions the respective tertiary research questions are answered.

8.1.1. Concluding on AJS Involved Actors

ONEgas is largely controlled and run by Shell. Direct signs are found in the use of the Shell logo on procedures and other documents as well as the participation in Shell programs such as Goal Zero. Safety is taken very seriously with stringent measures for violation of safety rules.

After previous experience with contractors Shell has set up ONEgas and contracted AJS by means of an Integrated Services Contract (ISC). Within ONEgas, AJS is an integrated department instead of a hired contractor. Due to previous experience with a different contractor, ONEgas focuses on eliminating any possibility of stretch in the budget.

AJS is a consortium of AMEC, Jacobs and Stork. The work is divided between East (NL) and West (UK). Jacobs and Stork divide the work in the East according to their specialization. AMEC performs all the work in the West. This division is also fed by the country borders, meaning other regulations in the two areas. The AJS jobs are split in three categories: Maintenance, Mods and Capital Projects. The first two category of projects are automatically granted to AJS through the ISC. The latter is to be won in a tender. Not winning the tenders on capital projects might cause unexpected effects to AJS.

Compared to onshore construction projects, AJS has a multitude of more Project Management functions more. These extra functions are necessary to do the work. This chapter provides an answer to the following three tertiary questions:

The first answer to question 1.2 "What AJS project data is recorded and available?" is short and simple. The Cost Report and CTR Manhour summary provide all data on the cost, schedule and Scope.

Secondly, the answer to the question 1.3 "How is AJS project performance measured by AJS? “ is that currently there is no formal procedure on performance measurement. Some indicators are used to keep track of the progress of projects. In the end the achievement of milestones determines the performance of a project. There are however no dedicated performance indicators.

The answer to question 1.4 "What (key) factors influence AJS project performance? “ is: As the work is specified in the deliverables, Scope and quality are thus fixed. Under the new contract the (estimated) schedule and cost are most important for achieving the milestones. On top of that ONEgas pressure AJS to be cost efficient. A proper estimate is of utmost importance since they determine the deliverables.

Also question 1.5 "Who controls the influencing factors? “ can be answered. The milestones and deliverables are set in meetings between ONEgas and AJS. ONEgas has the stronger position and determines what and when it will happen. AJS has a strong advisory role.
8.1.2 Concluding on Literature Review

After diving into the literature on the subjects of complexity, benchmarking, performance measurement and paradoxes of performance measurement, definitions per subject were established. Complexity for example is defined as four points that need to be fulfilled for something to qualify as complex. The definition of benchmarking found in the literature was restricted to match its purpose as a verb. This was necessary due to the large spread of goals and overlap of the literature definition with dedicated fields of research such as Quality Management.

The literature review shows that for the assessment of the AJS project performance, the use of the Project Management Triangle is most appropriate. The PMT proposes indicators on the Cost, Schedule, Scope and Quality. Data on the first three indicators can be found for any project, therefore allowing widespread application of the indicators. De Wit (1988) teaches us that Quality is a subjective indicator and can differ per actor. When measuring the performance it is thus important to measure several factors and put the results into perspective.

From the seven paradoxes, four were applicable to the current situation. The seven paradoxes’ main focus is not to move solely into one direction. They show that performance measurement can help monitor the progress but should not determine it. Accordingly performance measurements need to be put into perspective before they are acted upon. It is advised to leave space for negotiation and always bear circumstances in mind.

By means of the literature study, the five tertiary question were answered. Numerically ordered:

2.1 “What performance indicators from literature are suitable for AJS projects?”

First the Iron Triangle (Cost, Schedule, Quality) was taken as it proved to be the most robust option of performance measurement. It was however noted that situation specific additions to the Iron Triangle are possible. This addition was found in the Project Management Triangle which splits the Quality into Quality and Scope. This allows a separation of subjective (Quality) and measurable (Scope) Quality. Scope is assigned the milestones and PCR’s as performance indicators (PI). Cost is given Estimates, PCR’s and Actuals as PI’s. Schedule has similar Estimates, PCR’s and Actuals but then in man hours.

2.2 “How can the AJS project data provide the required information as required by literature?”

The Cost Estimates, PCR’s and Actuals can be retrieved from the Cost Report. Their Manhour namesakes can be taken from the CTR Manhour Summary. For further detail the PCR documents and NCR documents can be consulted.

2.3 “How can the AJS performance be influenced according to literature?”

The Project Management Triangle assumes, just like the Iron Triangle, that the whole is fixed and once started must keep it balance. Changing one parameter will thus result in a change in balance which the others points will have to compensate for. Depending on what change is desired, all the parameters need to be addressed. For example, an increase in Scope must be accompanied by an increase in budget and schedule in order to maintain quality.

2.4 “How does literature propose to counter the perverse effects of performance measurements on AJS projects?”

Similar to the balance in the triangles, literature advises to pay attention to common pitfalls and move into the gray area between two extremes. The seven paradoxes were applied to AJS in order to establish if and where the gray area was left and posed a problem.

2.2 “How can the findings on performance measurement based on literature be interpreted?”

The literature on Performance Measurement has not lead to standardized indicators. The most robust indicators found are Cost, Schedule, Quality and Scope. Several additions are possible depending on the perspective and importance of the goals. However, often this will only slightly change the impact of an indicator.

8.1.3 Concluding on AJS Projects

Chapter 1 pictured the influences to be taken into account when the actual construction work is done on location. The wind, limited capacity, high transportation cost and impact of missing parts is already taken into account during the design and planning of the construction. This means AJS has more Project Management due to additional tasks such as work packing. Offshore projects will thus always show a high amount of Project Management hours compared to onshore projects.
initiated when AJS receives a request for variation from ONEgas. Changes to Scope, schedule or budget can only be made by filing a PCR.

Information on the cost and PCR’s can be found in the Cost Report. The Estimated, Approved and Actual Manhours per project can be found in the CTR Manhour Summary. When more detail on the what, how or why is required, one can look into the filed PCR’s and NCR’s. A full paper trail is made to be able to track the process when looking back. All the possibly needed information is available.

Typically, the AJS categorizes projects in Maintenance, Modifications or Capital Projects. Smaller projects tend to have a larger share of Project Management hours. When small projects are compared to large projects, the small project will likely underperform while it might outperform other small projects. In order to prevent the comparison of such different projects, they are categorized into total cost categories based on a categorization within Jacobs.

The Current Cost Reports and CTR Manhour Summaries provide much information on the (development of) cost, schedule and Scope. This is however only applicable to the newer reports which have been filled precisely with relevant information. Prior to 2012 this information is less accurate and sometimes even incomplete. The date, subject or explanation can be missing or is unclear. In the newer reports this is rare, can however still occur. This detail might not seem relevant but is very important for the more in-depth look at the data.

When, for example, determining the reaction time after a certain file has been submitted for approval, the submission date and approval date are crucial information. When either one or even both dates are missing in the reports, an analysis of the reaction time cannot be performed. Even worse is registering any date, as this will sketch an incorrect image of the situation while wasting precious time.

The information of the Cost Reports and CTR Manhour Summaries is crucial when a management summary is desired because it gives an overview of the most basic information of a project: Cost, Scope and Schedule. It is thus key that these documents are continued for future projects in order to have an overview of the project. When the NCRs are filled in with more accuracy they may be used to determine the Quality of a project. Currently the Quality of the work can only partially be derived from the documents, as there is no indication of the link with the project process or resulting changes.

The answer to question 1.1 “What are the general characteristics of AJS Projects?” is thus:

• Mainly Offshore projects bound to a limited supply chain, high cost of transport.
• Changes frequent with at least one per project.
• Changes impact much of the work and resources.
• Mostly small projects (<500K)
• Extra Project Management functions are required to do the job.

3.1”How can the findings on current AJS project performance be interpreted? ”

Currently the performance of AJS projects is only noted as finished/unfinished and whether it had an over- or underrun of the project budget. Performance is thus very perception sensitive. More objective indicators are required to be able to compare different projects objectively. Given the amount of registered data on a project, the required data is likely to be stored already.

8.1.4. Concluding on AJS Benchmark

The created benchmark successfully deals, with help of the literature, with the set requirements. The performed literature study in combination with the available data has led to a semi-automatic benchmark in Excel. The tasks are automated by using VBA code. This allowed for reducing the tasks to clicking a button and selecting the required files.

Due to the small amount of projects the available data is not sufficient to give a statistical sound conclusion. It is also noted that there are extreme values which affect the average values. The figures are thus based on all fifteen projects.

Now that the combination of theory and practice has been made, a final answer can be given to the following research questions:

4.1“What AJS project performance indicators can objectively be compared? ”

Cost, Schedule can easily and without discussion be retrieved and compared. Quality on the other hand is much more subjective. It can however be split in Scope (measurable) and Quality as is done in the Project Management Triangle. Scope can then be measured in the number of (achieved) milestones and
changes to these milestones. Quality remains a subjective factor, in the literature it is often measured by interviewing or asking the client.

4.2 What tasks need to be performed in order to derive the AJS project performance indicators from the available AJS project data?

Normally the extraction of data from different sheets of the Cost Report and CTR Manhour Summary would be required. Specifically the estimate, approved and actual values are required along with the PCR data. This data would have to be found, selected and copied manually into a benchmarking file one by one. With the created Excel file this is reduced to clicking a button and finding the appropriate file, it even allows selecting multiple files.

4.3 What purpose can the AJS benchmark serve AJS?

The benchmark can provide an argument in the discussion around performance by comparing projects. The performance measurements can give an indication of where improvements can be made. How these improvements are to be made requires a separate analysis.

4.4 How can the AJS benchmark best be implemented?

The benchmark as constructed for finalized projects can best be used after all the documents of a project have been finished and the project has stopped. A good opportunity for this is in the close out phase.

8.2 Recommendation for Implementation of the Benchmark

With the answers to the tertiary questions, the sub research questions can be answered. The first question “How do current AJS projects perform?” can be answered with the following statements:

Due to the additional offshore factors playing a role in AJS projects, the percentage of Project Management on a project is expected to be higher than in a regular onshore construction project. The data from which the performance can be calculated is in the Cost Report and CTR Manhour Summary. These two reports account for the cost, schedule and quality, including any possible changes. The Scope tends to change in AJS projects because of changing client demands and desires. Performance is, according to the ISC, measured in achieved milestones. AJS is only rewarded when the agreed milestones are achieved. AJS has a strong advisory role in establishing the milestones, estimates on how long the work will take and what it will cost thus have a large influence on the milestones. These estimates are done by AJS as well as by ONEgas. The final estimate is a result of a discussion on the differences between those estimates.

The answer to the second sub question “How can the performance of AJS projects be compared according to literature?” is: the Project Management Triangle. An extensive literature review first lead to the Iron triangle of Cost, Schedule and Quality, as robust performance indicators. It is widely acknowledged that these indicators are the most robust but not exclusive to measure the performance. The Project Management Triangle offers a solution by splitting quality into Scope and quality, effectively separating measurable performance and perception. The Data on Cost, Schedule and Scope can be taken from the Cost Reports and CTR Manhour summaries. The data on quality will require a more thorough study. AJS can influence its performance by first determining several indicators and then comparing among projects, possibly even with competitors. For this a benchmark is necessary. Based on the performance AJS can decide how to act. Depending on what exactly underperforms, measures can be taken. It is best to perform a new study on the improvement of an aspect. Approaches for this can be found in the field of Quality Management. It is important to note that a performance measurement still requires human interpretation in order to value all the aspects properly. Seven paradoxes were found of which some were already applicable to AJS and ONEgas. The bottom line of the paradoxes is not go into extremes and not forget the interpretation.

Thirdly the question was put “How can the research findings be interpreted?”. The current performance of AJS projects is based mostly on perception with historical comparison with previous projects even though the data is available to do so. More objective indicators are required in order to come to an objective performance measurement. The literature, during 40 years, has not come to a set of universal indicators. Every author however uses the Iron Triangle with often a different version of perception measurement. The Project Management Triangle offers a suitable solution to this jungle of different approaches, by splitting the perception and Scope.

Finally the last sub question was: “How can AJS project performance best be compared to other (AJS) projects?” As the literature study pointed out the best way to objectively measure performance on AJS projects is the use of the Project Management Triangle. The Cost, Schedule and Scope can be retrieved after a project is finished, in the close out process for example, from the Cost Report and CTR Manhour Summary. The
estimate, changes and actuals are the value specifically needed. The benchmark can then serve in the
discussion around the improvement of projects. For the actual improvements a separate study is required.
The benchmark can best be performed after a project has been finished.

Coming back to where it all started, the main research question:

How can the performance of AJS’ complex engineering construction projects involving maintenance and
modifications of gas assets in the North Sea be monitored and controlled?

Combining all the answers above it can be said that the performance can be monitored by using
the Project Management Triangle and controlled by acting on the comparison of the different projects with
regard to the size of a project. The AJS benchmark is created in such a way that time, effort and required
knowledge are reduced to a minimum. The required data is however only available after the project has
completely been finished. It is therefore advised to incorporate the benchmark as one of the very last actions
in the close out process. When monitoring and acting on the measured and compared performance it is
important to keep the seven paradoxes in mind. When these are disregarded the action may very well have
the opposite effect. It is thus advised to only use the benchmark as a signaling tool and have a separate study
on how to improve the situation.

8.3. Importance of Interpretation

In order to compare AJS project data this study has focused on universally applicable performance
indicators. These were finally found in the shape of the Project Management Triangle which connects Cost,
Schedule, Scope and Quality into a closed and balanced loop. In order to make the indicators applicable
over a larger range of projects in all four the indicator ranges, the interpretation of performance is often
lost.

Though the target of universal performance indicators is to produce objective indicators without
need for interpretation, experience and literature show that when acting on performance, interpretation is
the key word. As shown by the seven paradoxes, acting on performance measurement can have a strong
impact on the measurement of that specific performance. The used Project Management Triangle in
combination with the Cost Report and CTR Manhour Summary do not leave any room for adjustment of
the numbers.

In this study the development of project performance was discussed and additional information on
the project performance was required. For the long term performance measurement it is important to have
a consistent measure method in order to trend any developments. Without a consistent measure method
the values would require correction of some sort.

With every performance measurement valuation it needs to be taken into account that every project
differs slightly. Even very similar projects may follow a very different project process to reach their end goal
given the circumstances during the project. It is thus very important to note these differences and combine
them to an explanation of the project performance. As said before in this report, the Benchmark only returns
a position of a project relative to the portfolio of compared projects. This notion is important as the
benchmark is fully dependent on the compared projects. It does not put a value on the position. A low
scoring project may well be an industry best. In order to make this difference between position and “good”
or “bad” an interpretation is required. From the explanation an interpretation of the project performance
can be derived. Based on the interpretation a value such as “good” or “bad” can be determined. The
interpretation is thus key in the discussion on the “good” or “bad” performance of a project.

Since every project is unique, every project would allow for an interpretation which always positions
the project in a “good” or “bad” performance ranking. Either way is possible in such an open interpretation.
The consistent measurement is then discarded, thus rendering the performance measurement useless for
trending. As the original problem centered around the trending of the project performance over time this
open interpretation space would thus not pose a solution to the problem.

The much needed interpretation space versus the consistency can be solved by discarding any
Outliers. Outliers are the most extreme values in a dataset. They often affect the measurement in an
undesired way. By discarding the Outliers there is no need to come up with an appropriate interpretation to
adjust the results as desired. Outliers could be recognized as the projects with values larger than 50% above
or below the expected relative values. These outliers could separately be categorized in order to keep track
of the developments in of the Outlier Projects. This separate categorization should also prevent the
adjustment of project performance to fall into the outlier category.
To summarize it is important to have some space for interpretation, too much space however can turn both good or bad for ONEgas and AJS. Either way the performance measurement cannot be used any more in future trending as it is customized instead of the required standardized.

8.4. Reflection on the Research

The target of this study was to take as much into account as possible in order to create a simplistic and pragmatic benchmark. Given the limited time, some subjects were not studied as intensively as the others. Although the knowledge on the subjects has been improved, it has still been found to be limited. These two reason lead to the coming remarks on the limitations of the work done. This is not to discredit the work or formulate any excuse, it is to show the work is limited and these limitations are acknowledged.

8.4.1. Difference of Offshore with General Construction Projects

In chapter 2 it was explained how offshore projects have a number of additional factors to take into account. These factors are weather, limitations on transport and storage capacity for both materials and construction workers, high cost of transport and the impact of missing parts. These conditions require a different approach with an increased focus on preparation of the materials before they are transported. This automatically introduces a number of management positions.

8.4.2. AJS Benchmark Limitations

Though the benchmark can compare several slightly different versions of Cost Reports it is still limited in a number of ways. Caution is advised when using the benchmark, as definitions among the sector, and even within AJS, differ. Within the construction sector for example performed tasks per company on a project differ. Take the example of Jacobs versus AJS where the last also provides additional tasks such as work packing. Even compared to projects in the same sector differences arise due to location (on- or offshore). Then there is the size of projects to be taken into account. The different sizes result in different ratios of for example Project Management.

Then there are the differences between AJS East and West where different governments and shareholders run their own regulations and systems. This results in slightly different expenses and working methods. This study has however not focused on these differences, use of the benchmark (results) is thus discouraged outside AJS East and if needed only to be done with great caution.

The developments in economy and technology need to be taken into account when comparing projects with a large amount of time in between. Take for example two projects which were finished with more than five years in between (eg. 2001 and 2014). It would then be wise to perform a short study on the inflation during that period.

8.4.3. Benchmark is a Comparison

A benchmark is a comparison, it merely shows if a project has a higher, the same or lower score than the others. When compared to a number of worse performing projects, a project will look as an over performer. Is the same project compared to better performing projects, it will look as an underperformer. The benchmark does not attach any objective or absolute value to the comparison. It merely shows how it a project is doing compared with the average. In order to improve a similar benchmark must be made across the sector.

8.4.4. Overlap of Benchmarking with other Scientific Fields

Benchmarking in the literature shows a very large overlap with analysis and improvement of the situation. Both the analysis and improvement have their own large scientific field of expertise and are consequently excluded from the benchmark itself. The resulting benchmark is thus a simplistic automatic comparison of numbers. The created code does not interpret or value any of the data, it simply imports and applies the calculations.

8.4.5. A Comparison is not a Valuation or Interpretation

The analysis of AJS and its projects has shown a large number of influencing factors. Interpretation is thus key when placing the data in a comparison. This might be lost when the data is incorporated into a larger dataset of projects. This loss of interpretation might then lead to an undervaluation of newly added projects as they are compared to outliers.
8.4.6. Small Number of Projects

Due to the requirement of finished projects and the required data, only a small number of projects qualified for use in the benchmark. Of the original twenty seven projects analyzed only twelve were finished. Seen statistically, the impact of outliers is currently thus very large. This has been taken into account by showing the outliers in the graphs. Their influence on the average should be taken into account when valuing the benchmark results.

8.4.7. Research Conditions

The author is a TU Delft Systems Engineering, Policy Analysis and Management (SEPAM) master student conducting his research at AJS Leiden. All data is provided by AJS. As AJS is an integrated part of ONEgas, it uses the ONEgas systems and procedures. The obtained data is also used by ONEgas and is thus considered objective. Most interviews were conducted with AJS employees and can consequently be biased. This bias has been countered by interviewing multiple employees on the same subjects. The influence of any bias is thus insignificant. The benchmark is made in VBA Excel where neither ONEgas nor AJS has any expertise and could thus have little influence.

8.5. Future Research

Given the limiting conditions mentioned in the reflection, this part is dedicated to future research opportunities that can improve the benchmark for AJS projects. The following research recommendations focus on the improvement of the benchmark as constructed and the insights gained by study.

8.5.1. Trending Projects

In the current state the Benchmark only allows the comparison of finished projects. Finished projects have the advantage of not changing. This allows an objective qualification of the project Cost, Schedule, Scope and Quality compared to previous projects. From a management perspective it would be more valuable to have such an insight during the project because the project may then be adjusted in the desired direction.

Such a benchmark of an ongoing project is however very complex to realize. The project needs to be compared to peers with similar indicators in Cost, Schedule, Scope and/or Quality. On top of that the project needs to be compared to peers in the exact same phase of the schedule. Given the different lengths of schedules this may prove very hard. A categorization similar to the cost categorization is advisable. The exact categories need to be studied for an appropriate fit. In an ongoing AJS project this is not easy to determine as the next PCR might raise any of the indicators above the predefined threshold. The difficulties are best displayed in the following example:

Take new project A, from which the budget is estimated at 450K and thus in the 500K range. The first PCR lets the project grow to 490K. Project A is thus still compared to 500K range projects. More PCRs come and go and the budget grows to 500K. The comparison to 500K projects is still correct.

Based on the comparison actions are taken to improve some of the quality and schedule performance. This has led to a lower % Project Management hours over the total hours compared to the average in the 500K range projects. Project A now scores well below average and is thus a good performer. As the Project Management Triangle prescribes a balance some of the Quality is lost due this reduction. Given the size of the project this is approved.

In the last stages of the engineering the client suddenly adds a major part with a total value of 150K. The timing is not ideal but the part can, with a little lower quality due to the pressure on time, be integrated with Project A. Additional Project Management hours are required, most of the previously saved are thus used. In the 500K range, project A is now just below average, only minimally outperforming the others. Due to the budget growth however, Project A now belongs in the 1000K range.

The average Project Management Hours over the Total are far lower in the 1000K range than in the 500K range. Project A thus performs very poorly in comparison to the 1000K range average. Also the Quality has gone further downhill and is now one of the worst in the category. Overall Project A can thus be considered a very bad performing project whereas it used to be a good one.

On top of the effect on performance the late addition of the part also has effects for the comparison of the project. The increased budget has led to an incorrect categorization of the project in previous phases. In this case the categorization of cost is incorrect, given the previously mentioned categorization by schedule
can also be incorrect. Any previous actions are thus likely to have been wrong, as was the case with the lowered quality, due to these mismatches. Trending can therefore only be accomplished when the project scope is not changed after the start of a project. This results however in a very inflexible organization as new insights or developments cannot be incorporated in ongoing projects.

It also needs to be added that the example assumes the data can be compared per time phase. Finding and matching the current time phase of a project to the time phase of peer projects is very hard due to uncertainty of the project data. From an ongoing project it can never be said with 100% certainty in exactly which time phase it is because an unexpected event may grow the budget, schedule, scope or quality demands. The change will then influence, as depicted in the PMT, the other indicators effectively changing the current performance of the project. What may have looked like a good fit of phase to compare in the past may after some event prove to be a very bad fit. There is thus a very large risk of mismatching time phases due to later changes when comparing ongoing projects. The causes and effects need to be assessed before such a comparison can be made.

8.5.2. Dynamic Code for the Future

The Benchmark in Excel consists of static VBA code meaning that when data is not in the predefined place in the input document the code will import the data which is in that place. Changing the location of this data can be done manually in the code, thus requiring knowledge on VBA coding. VBA has the potential to combine functions in order to automatically search for the required data. The limited time prevented the proper coding of such functions.

Since the creation of Cost Reports the format has changed slightly due to the preferences of the employees involved, such as Cost Engineers and Project Engineers. The code has been modified to correct for these small changes but remains static where it concerns the larger data sets. As a result more cells than necessary are imported in order to ensure that all the data is always retrieved. It is likely that similar changes are applied in the future, adjusting the code is then required but VBA coding knowledge is not available within AJS. Replacing the static code by a more dynamic version can make the benchmark more future proof.

8.5.3. Quality Assessment

For the current research the Project Management Triangle is applied in combination with cost and schedule performance. These parameters proved to be objective and available. A similarly objective and available approach for the quality assessment was only shortly looked into. In order to cover this in a scientifically proper way a separate study on this subject should be performed.

8.5.4. Effects of use and Actions on Benchmark

Due to the current lack of dedicated performance measurement and comparison with previous projects there are no apparent effects to be seen in the organization which can directly be linked to performance measurement. It is thus advised to have the effects of the performance measurement and benchmarking studied after implementation of the proposed benchmark.

8.6. Scientific Contribution

This research has provided an example of how a benchmark for offshore construction can be constructed. It details the steps taken for the benchmark to meet the requirements. Only one similar study has been found on the subject of offshore oil & gas companies. Statistically two is much too small a number to be able to give a statistical correct conclusion on the topic. This study has however doubled the amount of studies on the subject. Future case studies on this subject are thus necessary in order to provide a statistical sound basis for the subject.

Given the basic steps and the minimal use of data in this study, it can also be used as a framework in the future assessment of project data in any company. The Project Management Triangle indicators; Cost, Schedule, Scope and Quality are generally applicable for the analysis of projects. Data supporting any of the indicators can be found using the flowchart in Appendix C. When data is registered correct and precise, as is the current situation with AJS, finding the appropriate data is only a matter of selection. Quality will remain an subjective factor.

As quality is a subjective factor it is nonetheless interesting to develop a more general applicable understanding of project quality. Such an understanding could be made per sector.
In order to compare projects on an industry basis similar data needs to be collected from other companies. Though the study showed that different companies use a different formatting or divide cost or hours among different positions the overall indicators can still be used. For the exact comparison a transfer matrix of some sort will need to be established for the correct comparison of data. The provided steps on selection of data, automation of steps and benchmarking itself are generally applicable for establishing an internal benchmark tool.
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## Listings

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<th>Abbreviation</th>
<th>Explanation</th>
<th>Description</th>
<th>First Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA</td>
<td>Activity Allowance</td>
<td>Money, 10% of estimated cost</td>
<td>5.2</td>
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<tr>
<td>AJS</td>
<td>Consortium of Amec, Jacobs and Stork</td>
<td>Company</td>
<td>Front page</td>
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<td>BID</td>
<td>Basis for Design</td>
<td>Document</td>
<td>5.1</td>
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<tr>
<td>BDEP</td>
<td>Basic Design Engineering Package</td>
<td>Document</td>
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</tr>
<tr>
<td>CAA</td>
<td>Civil Aviation Authority</td>
<td>UK Government Body</td>
<td>1.1.3</td>
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<tr>
<td>CEP</td>
<td>Change Effect Point</td>
<td>Visualization of point</td>
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<tr>
<td>CTCE</td>
<td>Contractor Target Cost Estimate</td>
<td>Document / Estimate</td>
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<td>CTR</td>
<td>Cost Time Resource</td>
<td>3.5.5</td>
<td></td>
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<td>EBN</td>
<td>Energie Beheer Nederland</td>
<td>NL Government Subsidiary</td>
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<td>Energieonderzoek Centrum Nederland</td>
<td>Research Institute</td>
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<td>Électricité de France</td>
<td>Company</td>
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<td>E&amp;M</td>
<td>Engineering &amp; Maintenance</td>
<td>AJS Department</td>
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<td>FDP</td>
<td>Field Development Plan</td>
<td>Document</td>
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<td>FMC</td>
<td>Field Muster Copy</td>
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<td>GB</td>
<td>Gigabyte</td>
<td>Memory size</td>
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<td>HP</td>
<td>Hewlett-Packard</td>
<td>PC manufacturer</td>
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<td>IPA</td>
<td>Independent Project Analysis</td>
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<td>ISC</td>
<td>Integrated Services Contract</td>
<td>Contract</td>
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<tr>
<td>ITER</td>
<td>International Thermonuclear Experimantal Reactor</td>
<td>International cooperation of countries on nuclear fusion</td>
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<tr>
<td>KPI</td>
<td>Key Performance Indicator</td>
<td>Method parameter</td>
<td>4.3.1</td>
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<tr>
<td>LPG</td>
<td>Liquefied Petroleum Gas</td>
<td>Car fuel</td>
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<td>MOC</td>
<td>Management Of Change</td>
<td>Method</td>
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<td>Mods</td>
<td>Modifications</td>
<td>AJS project category</td>
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<td>NAM</td>
<td>Nederlandse Aardolie Maatschappij</td>
<td>Company, Dutch Crude Oil Company</td>
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<td>NCR</td>
<td>Non Compliance Report</td>
<td>Document</td>
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<td>Netherlands</td>
<td>Country</td>
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<td>Opportunity Realisation Process</td>
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<td>Project Management Triangle</td>
<td>Method</td>
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<td>Random Access Memory</td>
<td>PC part</td>
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<td>SEPAM</td>
<td>Systems Engineering, Policy Analysis and Management</td>
<td>Study</td>
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<td>SHEQ</td>
<td>Safety, Health, Environment and Quality</td>
<td>AJS department</td>
<td>3.5.5</td>
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<tr>
<td>TIC</td>
<td>Total Installed Cost</td>
<td>Sum of all cost</td>
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<tr>
<td>UK</td>
<td>United Kingdom</td>
<td>Country</td>
<td>1.1.3</td>
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<tr>
<td>VBA</td>
<td>Visual Basic for Applications</td>
<td>Programming language</td>
<td>6.5</td>
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## Appendix B. AJS Data Analysis

Table 3 Summary Project Data in the Benchmark

<table>
<thead>
<tr>
<th>CP No</th>
<th>Date start</th>
<th>Date end</th>
<th>Grand Total Project</th>
<th>(Actuals /CTCE )</th>
<th>[Actuals/ (CTCE+PCR+transf)]</th>
<th>Approved PCR</th>
<th>PCR(%)</th>
</tr>
</thead>
<tbody>
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</tr>
</tbody>
</table>
Appendix C. Flowchart Including Information as Benchmark Indicator

Flowchart: Include Available Information as an Indicator into a Comparison of Projects?

- **Start**
  - Is the information crucial?
    - Yes: Proceed to next question.
    - No: Not a crucial indicator: **DO NOT include in Benchmark**
  - What do you mean?
    - Yes: Proceed to next question.
    - No: Proceed to next question.

- **Can you use it to measure Cost, Schedule, Scope or Quality?**
  - Yes: Proceed to next question.
  - No: Not a crucial indicator: **DO NOT include in Benchmark**

- **Can you achieve the same without this or (also) with other information?**
  - With other: Proceed to next question.
  - Without: Proceed to next question.

- **Is it quicker or easier to use this information rather than the other?**
  - Yes: Proceed to next question.
  - No: Proceed to previous question.

- **Use the other information**

- **Can the exact same information be found earlier on in the process?**
  - Yes: Proceed to next question.
  - No: Proceed to previous question.

- **Why not use the earlier available information?**

- **Earlier available information is unreliable due to changes/incomplete information/etc.**

- **This is a crucial indicator: **DO include in Benchmark**

Also a good option. Let's look at the earlier information.

Lets look at the other information.
Appendix D. Flowchart Automate Tasks

Flowchart: Automate Tasks (1/2)

Start

Are the data documents of the same format?

- Yes
  - Can you arrange the data in the document in such a way that you can easily select the required data?
    - Yes
      - Save and spread the new arrangement as standard format.
    - No
      - Determine the standard location of the data within the document. E.g. sheet 2, column 5, row 11-120.

- No
  - Can they be made into the same format?
    - Yes
      - Can you automate the transfer of data?
        - Yes
          - Do so, it makes the transfer more reliable and saves time and effort in use.
        - No
          - Can you transfer the data to an Excel or Access document?
            - Yes
              - Can you automate any further actions?
                - No
                  - See next page
                - Yes
                  - No, they involve making choices
            - No
              - Do so, in both you can use VBA to automate any steps. Excel is preferred as almost any PC has it pre-installed.
    - No
      - Impossible, are you sure you have the root document?
        - Yes
          - Try selecting and copy-pasting data in another file like Excel. Try with ctrl+c for copy and ctrl+v for paste.
        - No
          - Find the root document. Then start again
      - Alright, got it
      - What is the “root document”?
        - The file in which the data is registered for the first time. This can also be in another program such as Primavera or SAP.
Flowchart: Automate Tasks (2/2)

Can you automate any further actions?

Yes

No, they involve making choices

Can you ease the appliance of the choices?

Yes

No

Do so, it makes the benchmark more reliable and saves time and effort in use.

Check

Can you ease the use of the benchmark?

Yes

No

Can someone use it without a specific procedure?

Yes

No

Do so, it reduces the possibility of incorrect use thus increasing reliability

Check

Describe the procedure in a (attached) manual

Check

Double check and your are done!
Appendix E. Excel Format Cost Report
Appendix F. Excel Format CTR Manhour Summary

<table>
<thead>
<tr>
<th>Column</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Activity ID</td>
</tr>
<tr>
<td>B</td>
<td>Activity Name</td>
</tr>
<tr>
<td>C</td>
<td>CTCE Budget</td>
</tr>
<tr>
<td>D</td>
<td>Appr. Budget</td>
</tr>
<tr>
<td>G</td>
<td>Act. Hrs Expended</td>
</tr>
</tbody>
</table>

Required Data
Appendix G. Excel Manual

List of already included projects, you don't have to include the project again if it is already in here.

List of Cost Report is on the left, CTR summaries on the right.

Manual in the document on the first sheet.
<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Type</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task 1</td>
<td>1.2MB</td>
<td>Task</td>
<td>May 2014</td>
</tr>
<tr>
<td>Task 2</td>
<td>3.4MB</td>
<td>Task</td>
<td>June 2014</td>
</tr>
<tr>
<td>Task 3</td>
<td>2.8MB</td>
<td>Task</td>
<td>July 2014</td>
</tr>
</tbody>
</table>

Select or Multi-select
Wait for the data to be retrieved. This will take several minutes.

Confirm data is retrieved (1/3)

Confirm data is retrieved (2/3)

Confirm data is retrieved (3/3)
Select projects to be compared in “comparison cost” sheet. This allows quick on/off switching of projects.
Appendix H. Additional Enlargement