Multidimensional Labor Resource Visualization for Integrated Turnarounds

MSc. Thesis: Construction Management & Engineering

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Period: From 07/01/2019 to 31/07/2019

Defense Date: 23/08/2019

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Executive summary

Turnarounds are of great importance to the refinery's competitiveness and profitability as they maximize production capacity and assure that the units are reliable and safe to operate, while still representing the single most significant identifiable maintenance expense in terms of direct costs and lost production. Due to turnarounds importance, their complex organizational nature, and the competitivity of the oil and gas industry, there is a pressure on refinery owners to maximize productivity during the execution phase of the turnarounds. Taking these characteristics of turnarounds as a starting point, this master thesis looks to develop a visualization concept proposed by BPRR that visualizes the labor distribution of the turnaround. The goal of the research is to develop a tool the enhances information interpretability and accessibility, causing improvement in coordination and communication during the execution phase of the turnaround. This research argues that the improvements in coordination and communication will reduce wasted time and therefore help to maximize labor productivity. The thesis explores the nature of organizational complexities that characterize turnarounds and, in conjunction with BPRR's needs, enters a design process following Dym & Little's Design cycle which will develop the tool to a useful level before testing it in BPRR's 2019 turnaround. The research is divided into two phases; the first phase covers the design process, which is divided into five chapters. The second phase covers the evaluation of the tool on the previously mentioned turnaround and is covered in one chapter.

Design Phase

The design phase of this thesis is divided into five chapters, each chapter representing a stage in Dym & Little's design process. The problem definition is the first stage of the design process. In this chapter, the thesis looks to contextualize the nature of turnaround complexities and operationalize definitions that will be recurrent through the research. This is done by conducting an extensive literature review based on the problem statement provided by the client. The findings from this stage are that turnarounds are indeed complex in the organizational aspect because of different aspects that contribute to these complexity like high internal strategic pressure, high schedule drive, short duration, large size of project team, large variety in task type & technical disciplines, high reliance on external stakeholders, lack of trust and experience with external stakeholders, high dependencies between tasks, high scope uncertainty & dynamism, lack of HSSE awareness and spatial conflicts. Based on the predominant organizational complexities, the literature review also evidenced the importance of organization coordination and communication for the successful execution of turnarounds. The literature review reaches a consensus on the criticality of labor productivity on turnaround as most of the scope is outsourced the client must adopt proper control strategies to prevent delays and extra costs. Because turnarounds have a massive flow of information and the need for this information to cascade through all relevant stakeholders, the study presents as a solution, the design, development, and implementation of information communication technologies to tackle this challenge. The need of a proper information communication technology in combination with an analysis on the drawback of standard PM Tools shows a gap and a need to integrate schedule, labor, and geospatial data which is in line with the client statement serves as the motivation to pursue the development of the visualization tool.

The second stage of the design process corresponds to the conceptual design of the visualization tool. The conceptual design has four main parts, the identification of the functional requirements set by the client, an analysis on the use of information systems common to turnarounds, the selection of visualization mean's technology and specific software, and finally the conceptual design based on the chosen technology and specific software's capabilities. This shows how GIS technologies cover the functional requirements set by the client as well as the interoperability requirements set by the common software used in turnarounds. The stage also conducts an extensive literature review providing evidence that GIS technologies can be used as project management tools were different cases show that these types of technologies are in fact valuable for project management functionalities. The stage then motivated the use of ArcGIS Pro, a leading GIS software with 3D capabilities, as chosen mean to visualize and integrate the intended data. The stage closes by setting an initial conceptual design based on ArcGIS Pros functionalities and proposes a modified space-labor cube with temporal animation as the initial concept to be developed in the subsequent stages.

The preliminary design is the third stage of the design process. This stage consists of adopting the client's initial proof of concept into ArcGIS Pro, making sure that the visualization covers all the functional requirements set by the client. This stage is divided in two first is the testing of the software capabilities using random data, and the second part is the command process made on ArcGIS Pro with actual data in order to get the functionality of the tool up to the initial functionality standards set by the client. The result of this stage is the successful visualization of the labor distribution covering all functional requirements set by the client and showing the implementation process using ArcGIS Pro.

The fourth stage of the design process corresponding to the detailed design is where the preliminary design is tested on a focus group composed of stakeholders directly involved with BPRR's 2019 turnaround. This stage looks to receive feedback from the intended users and implement a detailed design based on what the user's specific preference on the visualized information. In this stage, an introduction of the tool was given to the focus group followed by a pair of functional interviews which were conducted individually with each of the members of the focus group. The findings from this stage were that very much like other information systems the visualized data is very role specific as from the functional interviews it was found that the supervisors and are managers wanted the data to be visualized in different ways. This was an important finding in this stage because regardless of the information being shown, the different stakeholders appreciated the added value of the visualization tool, different applications. The supervisors were interested in the areas that contained their scope and the areas directly surrounding it, making a distinction between scope assigned to them and scope in the same area but assigned to other supervisors.

On the other hand, the Area-1 manager was interested in the complete scope of Area-1 but wanted the data to be visualized in two ways, the initially proposed visualization classifying scope by disciplines and a new visualization classifying scope by OBS. This new visualization shows the data but rather than have the colors represent the disciplines they colors would now represent the different contractors. The result of this stage was the detailed design of each visualization scene specific to the focus group member's individual needs.

The final stage of the design cycle is the design communication. In this stage of the design process, the final decision on what would be made available for the evaluation phase was pinpointed. Differentiating from the initial scope to only visualize one scene covering only the scope of Area-1. Due to the role-specific desires from the different members of the control group, four different scenes were developed and implemented. The first scene covering Area-1, Area-2 & Area-3, this scene differentiates scope by color and has the functionality of filtering out areas or specific disciplines. The second scene was corresponding to the Area-1 manager with the classification of scope in two ways, by discipline, and by assigned supervisor also allowing the scope to be filtered by the specific supervisor. The two leftover scenes correspond to the specific scope of the two supervisors in the focus group, these two scenes classify scope by discipline but differentiate the scope assigned to the supervisors, the scope in the supervisor's area but assigned to a different contractor, and the scope surrounding the intended supervisor's area. These scenes were made available during BPRR's 2019 turnaround

Evaluation Phase

The evaluation phase consisted on testing the designed tool on BPRR's turnaround 2019. The evaluation was done by conducting interview styled surveys with the supervisors and an earned value analysis. The findings from the EVA were inconclusive as it is tough to pinpoint how exactly the tool influenced the contractor's productivity as there are many factors affecting productivity. The exciting findings in this stage correspond to the survey were the supervisors graded the tool on its usefulness for enhancing communication, coordination, and even reducing wasted time. The tool was positively graded were the supervisors were genuinely interested in the further development of the tool as they argue that if applied on a full scale, the real benefits of the tool will be evident. Another interesting finding was how the supervisors found other uses to the visualization tool as they argued that the tool could be implemented from the planning phase to level labor resources and for early detection and prevention of simultaneous operations. During the execution phase, the research was published in the BPRR newspaper were Mistras nondestructive testing contractor read the article and asked for their scope to be visualized. This is an important case for the evaluation of the tool as a stakeholder outside of the focus group saw the added value of the visualization tool and argued that the tool would help them in their struggle to get their personnel in the right place at the right time. This Case with Mistras goes in line with comments from the supervisors as they argued that contractors would benefit a lot from the tool, which shows that there is a need in turnarounds that the tool seems to cover.

Conclusions

The research reaches the following conclusions; The integration of labor, schedule, and geospatial data to tackle the client's problem statement was proved to be the correct decision based on findings from an extensive literature review on common project management tools, on turnaround characteristics, on the importance of coordination and communication within the turnaround organization, on the need to implement a new information communication technology, among others. The research also found that GIS technologies were the perfect mean to implement the visualization tool as a literature review on the technology proved that it had the capability of covering all requirements set by the client. This was confirmed with the resulting tool and the satisfaction of the client. Given the comments and evaluation made on the tool were stakeholders agree that the tool is useful and should be further developed. The research tried to prove that the tool improved labor productivity, but the results were inconclusive. This does not mean that the tool was unsuccessful, this means that the way in which the visualization tool was implemented and the way in which the labor productivity measured did not show enough supporting data to confirm or deny that the tool enhances labor productivity. With this in mind, it was proven that the tool does have a great potential in doing so. The researcher suggests to truly see the effect of the tool on productivity it should be implemented on an organization level, stakeholders should be trained on how to use it and should be applied since the planning stages of the turnaround. Along with the research, many different applications have been discovered on the use of geographic information system (GIS) technologies leaving many further researched originating from this one.

Contents

1. Introduction

This research project focuses on integrated turnarounds. A turnaround is a periodical maintenance project that is conducted on industrial process plants. This type of maintenance project consists on the shutdown and dismantled of the processing unit for a certain period while maintenance activities, like inspections, repairs, replacements, and overhauls, take place (2009, Ben-Daya et al.). Turnarounds are strategically planned to last as short as possible because each day the unit is off service a significant production loss is acquired, making these types of projects highly schedule driven (2011, Bevilacqua, et al.). Integrated turnarounds are turnarounds that include both maintenance and project scope, which maximizes production capacity and ensures that equipment is reliable and safe to operate. Because of this, integrated turnarounds are massively relevant to the industry.

KPMG's global construction survey (2015) found that out of 109 projects, 53% were underproductive in meeting target cost and schedule. This situation is more critical in the oil and gas industry, a study published by Ernst & Young Global (2014) shows that from 365 oil and gas megaprojects, 64% faced cost overruns and 73% suffered schedule delays. Specific to turnarounds Joshi (2004) in a benchmarking study for more than 200 turnarounds, proves that most turnarounds experience schedule slips and costs overruns that are caused by inadequate planning and coordination. Planning and coordination are so complicated in turnarounds because of a conglomerate of complexities that characterize these types of projects which were found by conducting an extensive literature review. From this literature review, it was also discovered that turnaround projects are predominantly complex in the organizational aspect.

The research analyzes the standard practices of PM tool usage in turnaround projects and finds that common PM tools do not fulfill the needs of the project characteristics. Consequently, an analysis was made on the importance of information communication technologies and how they aid communication, coordination, and therefore, the organization. Based on these findings and having in mind the complex characteristics of turnarounds like the high amount of labor resources and the lack of resource visual representation in the PM tools, it was clear that there is a gap in the standard PM tools used in turnarounds.

To tackle this gap, a literature review was conducted on multidimensional visualization models that integrates schedule, labor resource, and geospatial data. In this review, few but promising developments were found on the benefits of incorporating labor resources into a visualization tool. The gap encountered will set the direction of this research, which is the design and development of a visualization tool that integrates schedule, labor resources, and geospatial data. The goal of the thesis is to provide a tool that tackles turnaround's organizational complexities by improving coordination and communication within the turnaround team. Because coordination and communication are improved, the visualization tool should cause a positive effect on productivity, and therefore, a positive impact on the outcome of the turnaround.

This research will then look to develop this visualization tool and to evaluate its usefulness on a real-life turnaround. Because of this, the research is divided into two phases a design phase and an evaluation phase. The design phase will follow a five-stage design cycle where the tool will be developed based on the client's needs, while the evaluation phase will consist on implementing and evaluating the tool on BP Rotterdam refinery's TAR2019.

2. Research

2.1. Research Problem Statement

Turnarounds are very significant to the oil and gas industry, and to the owner, as these type of major maintenance projects, have a substantial effect on the level of competitiveness of the refinery. This is because turnarounds assure a level of production capacity and ensure that equipment is reliable and safe to operate. Regardless of the importance of these type of projects, turnarounds are characterized by different kinds of complexities that make said project very complex to execute, especially in the organizational aspect. Because of this, the research will focus on two aspects. First, the need to reduce wasted time to prevent delays and assure that the turnaround minimizes production loss. And secondly, the importance of labor productivity during the execution phase, as this labor productivity will set the rate to which value is added to the project which is vital especially when considering the first aspect on the importance of production loss of the refinery to its business. Because of this, the research will adopt the following problem statement:

"Regardless of the importance of turnarounds for the oil and gas industry, their effect of the overall competitiveness of the refinery, and the amount of time and resources spent planning these projects. Turnaround managers are still struggling on successfully executing turnarounds due to the organizational challenges that characterize these types of projects."

Chapter 3 on Problem definition will provide more information to contextualize turnarounds, their complex nature and their relevance to the industry.

2.2. Research Hypothesis

Based on the previously exposed research problem statement and the client statement found in Chapter 3 on problem definition, the following double hypothesis will be adopted for this research:

"The integration of schedule, labor, and geospatial data into an open visualization tool will have a positive effect on coordination and communication, which will improve labor productivity during the execution phase of Integrated turnaround projects."

2.3.Research Goal/ Objective

The goal of the research is to develop, based on the client's problem statement, a visualization tool that integrates labor schedule and geospatial data and to test the usefulness of the visualization tool during the execution phase of a real-life integrated turnaround. The specific Integrated turnaround, where the usefulness of the tool will be evaluated, will be introduced in Chapter 3 on problem definition.

2.4. Research Questions

The main research question will drive the objective of this research and is supported by complementing sub-questions. The main question will look to tackle the research objective, which is to develop a tool that visualizes the integrated schedule, labor, and geospatial data and to test whether that tool improves labor productivity. Given the objective, the main question is as follows:

> How does the implementation of a multidimensional visualization tool that integrates schedule, labor, and geospatial data, provide the means to maximize labor productivity for integrated turnaround projects during the execution phase?

This main question cannot be answered by itself. For this reason, a set of sub-questions will complement the main research question.

1. Why would labor productivity, during the execution phase of the turnaround, benefit from the integration of schedule, labor, and geospatial data into a multidimensional visualization tool?
2. Which visualization technology better suits the integrated turnaround's needs?
3. Do the stakeholders appreciate the visualization tool as a tool that enhances coordination and communication during the execution phase of the turnaround?
4. Does the implementation of the visualization tool, on the TAR2019, evidence improvement of labor productivity?

Each sub-question will help answer the main question in the following way; sub-question one will set the nature of the client's problem statement. The second sub-question will evaluate the visualization means to fit the client's requirements. The third sub-question will look to test the tool in the TAR2019. And the fourth sub-question will look at whether there is enough supporting information that proves if labor productivity actually improved during the TAR2019. By answering all these sub-questions, the main question will be answered.

2.5.Research Methodology

This research has two phases the initial design and development phase were the initial proof of concept provided by the client will be developed based on literature reviews and the assignation of a focus group. The second phase of the research is a causal study where the effect of the developed tool will be evaluated on the turnaround. Because of the previously described nature of the research, the methodology will adopt a modified Dym & Little design cycle. Dym & Little's design cycle is a framework that structures the design process of a product into a 5-stage iterative process (Dym & Little, 2008). As stated, the research scope goes a step further than the limitations set by the original Dym & Little design cycle. For this reason, the framework must add a stage were the designed tool's usefulness, and causal effect will be evaluated on the TAR2019. This stage will be called the evaluation stage.

The reasoning behind adding the evaluation stage in this research is because this thesis looks to generate a process in which the developed tool is implemented and causes an effect on the onsite personnel. To prove that the process works the tool must create a strong enough signal that will influence the working process and therefore, the output of the project. Keep in mind that the term tool used is not only for the visual platform; it is a system composed of the integration between the platform used, the data inflow, and the users. The research would then like to create knowledge through the transformation of experience. As the goal of the research is to test the effect of the tool on the turnaround, it can be said that the Dym & Little cycle will be a design process to develop the initial proof of concept in order to meet the user's needs. Once the detailed design is done, and the system is ready to be tested on the TAR2019, the evaluation stage comes into play. The methodology will look to solve the main question and the sub-question, which will consequently prove the validity of the hypothesis. To do so, each stage of the methodology, as exposed in figure 1, will be described.

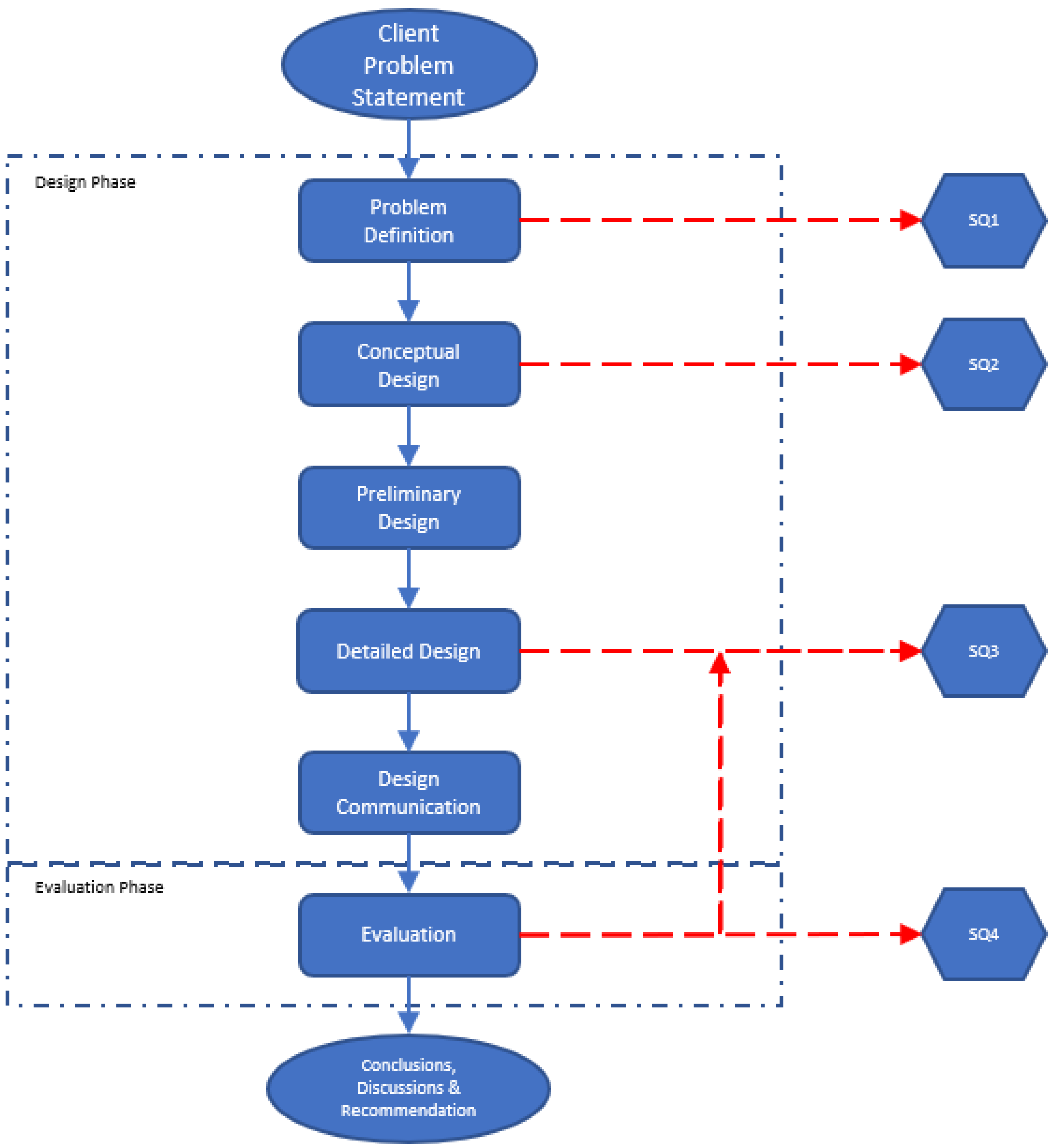

Figure 1: Research Methodology

2.5.1. Problem Definition

This first stage of the design cycle is the problem definition. This stage will initiate with the introduction of the client and his problem statement. This stage will revolve around the client's problem statement and describes the concept that the client wants to develop. This stage will also introduce the case description in which the visualization tool will be evaluated. Also, essential definitions of recurrent concepts relevant to the research will be added to avoid confusion. Finally, the problem identified by the client will be contextualized on a general industry level in order to refine the nature of the problem. The goal of this stage is to gain a better understanding of the client's problem and thus generate sufficient background knowledge to enable a knowledge backed solution to the problem. To achieve this, this stage will produce a detailed literature review. The result from the literature review will arrive at a conceptual model that sets the answer to the first research sub-question which describes the reason why coordination and communication , during the execution phase of the turnaround, would benefit from the integration of schedule labor and geospatial data into a visualization tool.

2.5.2. Conceptual Design

According to the Dym & Little cycle, the conceptual design stage consists of establishing preliminary design specifications, requirements, and functions set by the client, assess restrictions, chooses an ideal visualization means and generates conceptual design alternatives. As a starting point for the conceptual design, the research will take the preliminary proof of concept and its requirements. With this information, the study will analyze the restrictions set by the client's current practices. Subsequently, an investigation will be made on the technology that ideally covers the design needs established by the preliminary requirements of the client. To properly verify that the technology fits the requirements, this stage will also conduct a literature review on the standard practices of the uses of the technology under the client's context. This will verify if the technology suits the needs of the client, and therefore answer the second sub-question of the research. With the technology chosen, the research will then look to consider different design alternatives focusing only on the preliminary requirements and the capabilities of the selected platform.

2.5.3. Preliminary Design

The third stage of the Dym & Little cycle focuses on the actual development of the conceptual design into a preliminary design. In this stage, the established conceptual design will be developed through the visualization mean chosen. The stage describes, on a technical level, how conceptual design is refined and optimized to meet the performance and operating requirements while evidencing the restrictions found along the development process of the said concept. The goal of this stage is to develop the conceptual design as much as possible to be able to visualize the initial proof of concept into the visualization mean. The end product of this stage is a detailed description of the operations and queries used to visualize the desired data and thus plays an essential role in the deliverables of the research.

2.5.4. Detailed Design

The detailed design phase of the research will take as a starting point the developed result from the preliminary design phase. The goal of this stage is to fine-tune the design by getting feedback from the stakeholders. This will be done by taking a focus group assigned by BPRR and conducting functional interviews to start testing the functionalities of the visualization tool and detailing the visualization to fit the user's needs. The result of this stage will be the description of the whole feedback process and the consequent changes in the design of the visualization tool. This stage is crucial for the evaluation phase, as it makes sure that the product fits the user's needs. Part of Sub-question three will be answered in this phase as feedback will be received on the visualization tool.

2.5.5. Design Communication

Design communication is the final stage of the Dym & Little design cycle. This stage is dedicated to expressing and documenting the final design. For this stage, the research will make some remarks on the design process and will expose the agreed-upon design, which is the final outcome of the design phase. This chapter also plays an integral part in the deliverables of the research as it describes the characteristics of the visualization scenes that will be implemented and updated during the evaluation phase.

2.5.6. Evaluation

The evaluation phase of this research corresponds to the causal study used to evaluate the resulting visualization tool of the design cycle. In this stage, the tool will be provided to the focus group for its use during the TAR2019. The tool will then be evaluated in three ways first qualitative on-site observations will be conducted to assess the quality of the visualization tool. An earned value analysis (EVA) which analyses the extent to which the subject being evaluated performed according to the base plan schedule. And finally, once the TAR2019 finishes, interviews will be conducted on the experience with the visualization tool and also quantitative evaluation of the tool via graded surveys will be made. Complementing the feedback received in the detailed design this tool will finish answering sub-question three. The results from this stage will then answer sub-question 4.

2.6. Research Deliverable

The deliverables of the research will be as follows; the detailed description of the development of the Proof of concept. Detailed findings from the interviews with their effect on the development of POC. An earned value analysis on the supervisors on which the tool was tested, and interviews and surveys conducted on the supervisors that used the tool. The research will also deliver, based on the design and evaluation phase, conclusions of the findings of the research which includes the answer to the hypothesis, answer to the main and sub-question, limitations of the research, recommendations to the company, and recommendation to future researchers.

2.7. Evaluation Scope

The scope of TAR2019 is divided into three areas covering different functional units. With the motivation of proposing a study that is doable in time and not overly ambitious, the scope of the research will be fixed to the most critical Area of the TAR2019. The most critical area is Area-1, which includes the most scope significant and most complex unit, which is the Crude distillation unit. This will then reduce the scope of the methodology as the development of the POC will be tested for user experience, interface friendliness, and tool usefulness on the Area-1 manager, and Supervisor-A and Supervisor-B both assigned to Area-1 as well.

3. Problem Definition

This chapter will cover the first stage of the Dym & Little design cycle, which is the problem definition. This stage will revolve around the client's problem statement, which describes the concept that the client wants to develop. This chapter is divided into three subchapters. The first subchapter will be dedicated to introducing the client, the client's problem statement, and the case description. The second subchapter will introduce definitions to set critical concepts that will be recurrent in the research. The third subchapter will be a literature review on the nature of the client's problem statement. The goal of the third subchapter is to prove whether or not there is enough supporting evidence on the relevance of the client's problem statement on a general industry level.

3.1.Client

This research will be executed between TU Delft and BP Refinery of Rotterdam B.V. This subchapter looks to introduce, with a basic overview, the company, the client statement, and the specific case description of the integrated turnaround TAR2019.

3.1.1. BPRR

BP plc is an integrated energy company founded in the early 1900s in the United Kingdom. Their portfolio covers a wide variety of services like raw material extraction, oil and gas explorations, resource transportation, storage, trading and supply, oil refining, gas station services, and wind & solar energy production. Oil Companies usually make a differentiation on searching and extracting raw material with the processing and refining of the raw material into a modified product. The searching and extracting sector of the business is referred to as the upstream sector. On the other hand, the processing and refining sector of the business is referred to as the downstream sector. In the downstream sector, BP plc owns a wide variety of plants that are dedicated to producing different petrol and gas-based products. BP Refinery Rotterdam B.V. (BPRR) is a subsidiary branch of BP plc which Operates in Rotterdam Europoort. BPRR focuses exclusively in the downstream sector of the oil industry, focusing on the refining of fuels. Due to its strategic location and its storage capacity and the shipping installations, a large part of BP's supply of fuels to inland Europe passes through the Rotterdam location giving the refinery great importance to the BP group. BPRR has one of the largest refining capacities of crude oils in Europe. Its plant produces up to 400,000 barrels of oil per day. BPRR also has an extensive storage system with a capacity of 4.3 million cubic meters. Their main production outputs are liquefied petrol gas, motor gasoline, marine fuels, diesel, kerosene, and heating oil. BPRR also possess loading installations for loading and unloading products, suitable for both inland and sea vessels. The research will be developed and tested on an integrated turnaround that BPRR will undergo in 2019.

3.1.2. Client Statement

As the owner of the refinery, BPRR needs to regularly execute maintenance work for the refinery units to maintain the desired production level and to prevent undesired downtime. Due to the characteristics of the oil and gas industry, refinery owners usually undergo massive maintenance projects called turnarounds.

Due to the volatility and the competitive environment of the oil and gas industry, BPRR is consistently trying to improve their processes and make the business sustainable. In recent years there has been a drive from companies to achieve sustainability through productivity. This drive refers to the idea that by using resources more efficiently, BPRR will reduce wasted resources and therefore bring a competitive advantage to the company.

With the historical experience of BP downstream sector and more specifically, BPRR's experience on previous turnarounds, there is a consensus agreeing that turnarounds are crucial to the refineries competitiveness and therefore to BP business. Because of the importance of these type of maintenance projects and their inherent complex nature, BPRR is continuously trying to improve their processes to achieve an increased level of sustainability.

BPRR argues that turnarounds are much more complicated on an organizational level rather than a technical one, mainly due to the high schedule drive of the project and due to the outsourcing of most of the maintenance project's scope. This increases the amount of different and specific contractors and therefore, personnel required to execute the diverse tasks that compose turnarounds. This immense amount of outsourced work and the high schedule drive requires rigorous control of the contractor from the client's behalf to achieve the set goals on schedule, safety, quality, and costs.

BPRR Downstream historical data shows that due to the organizational problems that turnarounds are characterized for, there is a lack of coordination and communication, which is inherently affecting the labor productivity of the on-site personnel during the execution phase of turnarounds which has effects on the success of the project. This information comes from time on tools analysis made by BPRR, which measures the labor productivity of the on-site personnel. The time on tools made by BPRR shows that the actual time spent on productive work is 40%. The remaining 60% of the time is attributed to different sources. The most representative attributes to unproductivity are laborers found performing work in the wrong location, laborers not found in location and not performing work, and personal breaks.

Given the results of the time on tool analysis, BPRR argues that they have problems getting the right people at the right time in the right location. With this problem in mind and with three consecutive turnarounds (TAR2021, TAR2022, TAR2023) around the corner, BPRR is considering the development of an interactive 4D tool that visualizes labor distribution in the refinery during the turnaround's execution phase. The goal of the tool is to visualize labor, geospatial, and schedule data in a way that is more accessible and interpretable to the stakeholders during the execution of turnaround. By achieving this, there will be increased coordination and enhanced communication, which will have a positive effect on labor productivity and therefore make turnarounds more business sustainable. BPRR project control team for TAR2019 has made an initial proof of concept for the tool that can be appreciated in Appendix A. BPRR wants to develop this tool so it can be tested in the TAR2019 and from there make an informed decision on the usefulness of the tool and whether further development is feasible.

3.1.3. Case Description

As described in the client's problem statement, BPRR wants to initiate the development of this 4D Tool to implement it in future turnarounds. As three consecutive turnarounds are coming up, BPRR wants to develop the initial concept of the tool so that it can be tested on TAR2019 and a decision be made whether further development is feasible. As the tool will be tested on TAR2019, it is relevant to give a general introduction on TAR2019.

In May 2019, BPRR will initiate the execution of the TAR2019 (Turnaround 2019). TAR2019 will carry out major maintenance tasks as well as project-oriented tasks. The maintenance scope covers the inspection, repairs, and revamping of the current units adding up to an estimated cost of € 50 million. The project-oriented scope of the TAR2019 entails various projects and microprojects that serve to upgrade different units adding up to an estimated cost of € 80 million. These projects aim to upgrade equipment and introduce new technologies to improve the speed and efficiency of the refinery. Both scopes sum up to an estimate of € 130 million and entail over 20000 scheduled activities with 250000 to 300000 man-hours, outsourced to as many as 120 different contractors, all of which are scheduled within a time frame of 4 weeks.

The TAR2019 will focus on different units scattered through the refinery and is divided into three areas. The main units that Area-1 cover are a crude distillation unit (CDU3), a distillation hydrotreater (DHT), and a distillation fractionation unit (DFU). The most critical unit in Area-1 is the crude distillation unit (CDU3). The plot for Area-1 can be found in Appendix C. The primary scope for this area covers:

- The replacement of the crude distributor and distillation pack;
- The replacement of 4 exchangers (E2102);
- The replacement of 14 air fin banks (E2112);
- The replacement of the demister pack for the crude overhead drum;
- The replacement of HGO dryer/stripper tower (T2103 & T2105);
- And, the construction of new sidewalls and a new roof for the splitter reboiler furnace (H2201).

Area-2 covers a catalytic reforming unit (CRU), a liquified petroleum gas unit (LPG), a gas oil hydrofiner unit (GOH2), and electric substation A and B (Sub A & Sub B). The most critical unit in Area-2 is the catalytic reforming unit (CRU). The plot for Area-2 can be found in Appendix D. The primary scope for this area covers:

- The removal and reconditioning of Compressor C501, as well as modification of its seals;
- The testing and replacement of the center pipe for Reactor 503;
- The testing for the passes on Furnace 501;
- The replacement of the catalyst for three reactors;
- The replacement of nozzles of towers 603 (rich oil stripper) and 604 (propane & butane splitter), as well as the installation of a new platform for the LPG unit;
- The installation of new switchboards for Substations A&B;
- And, the replacement of three transformers for Substation A.

Area-3 covers a gas oil hydrofiner (GOH1), a sulfur recovery unit (SRU-C), and a flare (Flare1). The most critical unit in Area-3 is the gas oil hydrofiner (GOH1) The plot for Area-3 can be found in Appendix D. The primary scope for this area covers:

- The replacement of stripper tower T801;
- The replacement of the catalyst for Reactors 801 and 802;
- The replacement of product pump 802;
- The inspection and repair of Furnace H801;
- And, the entire replacement of flare 1 including both the sour gas tip and a hydrocarbon tip.

3.2. Definitions

This subchapter is a literature review that will set some definitions of concepts that are recurrent in the research. This subchapter is divided into five sections where each section will set a definition to be used along with this research. The terms to be described are Turnarounds, Integrated Turnarounds, productivity, labor productivity, and time on tools.

3.2.1. Turnarounds

Most process industries (petrochemical, refining, power generation, water treatment, steel plants, among others.) require a plant to provide their services. Industrial plants are complex processing systems, composed of different equipment and machinery, that aim to deliver an industrially modified good (2011, Bevilacqua, M. & Ciarapica, F., Giacchetta, G., & Marchetti, B.). As these different equipment and machinery are subject to stressful operating conditions, they deteriorate and therefore must be maintained to assure the required levels of reliability, quality, safety, and performance of operations (2009, Ben-Daya, M. & Duffuaa, S.O.). Because of market conditions and challenging environment, a reliable production system is a crucial factor for competitiveness, almost all the processing and manufacturing sectors are required to maximize availability and efficiency of equipment, controlling failure and deterioration, guarantee a safe and correct operation and minimizing the costs (2011, Zhaoyang et al.).

Industrial plants are generally divided into processing units. These processing units are a conglomerate of different equipment and machines that are integrated into a continuous production line that modifies the input streams. Meaning that the different parts of the processing unit are interrelated, and the system will not work if one of the components fails or is out of order. Because of this characteristic of the processing unit is partial maintenance or inspection will require a complete shutdown of the unit as the continuous production line would be broken. Because of this, it is unfeasible to shut down the unit every time it needs maintenance. For this reason, owners make a single shutdown of the unit to allow for inspections, repairs, replacements, and overhauls that can be carried out only when the assets (plant facilities) are taken out of service. Such maintenance projects are called turnarounds, a concept that originated in process industries, and it plays a vital role in maintaining consistent means of production delivered by reliable equipment.

A turnaround then is a periodical maintenance project that involves total shutdown of the unit and consist on restoring modifying or upgrading components with the aim of increasing the energetic efficiency, guarantee a homogeneous functioning and the integrity of the security systems, limit the wear to increase the service life (2011, Bevilacqua et al.). During turnarounds maintenance activities, like inspections, repairs, replacements, and overhauls, take place focusing on critical equipment, that is not possible to isolate during the normal functioning of the plant, and those that have shown problems or need a periodical inspection (2014, U. M. Al-Turki, T. Ayar, B. S.Yilbas, & A.Z. Sahin). Duffuaa and Raouf (2015) characterize the scope of work that is commonly conducted during turnarounds as follows:

- Work on equipment which cannot be done unless the whole plant is shut down;
- Work which can be done while equipment is in operation but requires a lengthy period of maintenance work or a large number of maintenance personnel;
- Defects that are pointed out during operation, but could not be repaired, will be maintained during the turnaround period;
- Upgrading equipment and introducing new technologies to improve speed and efficiency.

The objective of turnarounds is to maximize production capacity and ensure that equipment is reliable and safe to operate. The underlying objectives of turnarounds, according to Ben-Daya & Duffuaa (2009), are:

- To improve the efficiency and throughput of a plant by suitable modification;
- To increase reliability/availability of equipment during operation;
- To make the plant safe to operate till next turnaround;
- To achieve the best quality of workmanship;
- To reduce routine maintenance costs;
- To upgrade technology by introducing modern equipment and techniques;
- To modify operating equipment to cope with legal requirements and or obligations such as environmental regulation;
- Achieve budget figures and ensure the forecasted economic life of the assets is achieved.

Now that Turnarounds have been introduced on a general level, exposing their motive, scope, objectives, and underlying objectives, the term Integrated turnaround must be defined in order to be aligned with the terminology and concepts used at BPRR.

3.2.2. Integrated Turnarounds

Given the previous introduction to turnarounds, it is evident that even though turnarounds are considered mostly maintenance work, the underlying objective of upgrading technology by introducing modern equipment and techniques does not necessarily fall under maintenance scope but are generally considered as separate projects. These projects vary in scope and size depending on the specific turnaround, but the important point is that regardless of the difference between maintenance scope and project scope is that the tasks within those scopes are generally executed in the same shutdown period and the same area. For this reason, and in order to prevent confusion in this research, the term “turnaround” should be read or interpreted as a synonym to the term “integrated turnaround”. Integrated turnarounds include both maintenance and project scopes, were in the define phase of the turnaround; tasks for both scopes are planned without any differentiation. The decision to adopt this term is in line with the client's practices and with the turnaround where the tool will be evaluated. The research will make a distinction between project and maintenance scope, if necessary, by explicitly using the terms “maintenance scope” and “project scope”.

3.2.3. Productivity

It is clear from the client's problem statement that their goal is to maximize or improve labor productivity. Before diving into labor productivity in turnarounds, it is first essential to pinpoint a definition of productivity that will be used through the research. This is done to set the direction of the research and to reach a consensus on the wide variety of interpretations on productivity.

Tangen (2005) in his research attributes the variety of interpretations of productivity to the multidimensionality of the term; this suggests that the meaning of the term varies depending on the context in which it is used. Regardless of this, Tangen (2005) also argues that common characteristics can be found in the different interpretations of the term. The common characteristic that defines productivity at a general level is the relation between input and output. Where Input is the consumed resources and output is the produced good. Bernolak (1997) provides a valuable general explanation of what productivity entails:

"Productivity means how much and how well we produce from the resources used. If we produce more or better goods from the same resources, we increase productivity. Alternatively, if we produce the same goods from lesser resources, we also increase productivity. By "resources", we mean all human and physical resources, i.e., the people who produce the goods or provide the services, and the assets with which the people can produce the goods or provide the services. The resources that people use include the land and buildings, fixed and moving machines and equipment, tools, raw materials, inventories, and other current assets."

This explanation points out important aspects of productivity. It differentiates the level of production from productivity. Level of production would only be how much is produced. Productivity, on the other hand, will include an analysis of how efficient the use of resources is given the production level. This proves that an increase in production level does not represent an increase in productivity. The reasoning behind this is the link between productivity and use and availability of resources as well as the creation of value, which means that productivity is affected by the correctness in which resources are utilized, as well as the availability of the resources when the specific resource needs to be used. Also, the level of productivity is dependent on whether the activities and resources (input) add value to the produced good (output). From Bernolak description Tangen (2005) concludes that to improve productivity waste must be eliminated.

3.2.4. Labor Productivity

From the previous description of productivity, it has been established that productivity on a general level is defined by the ratio between input and output. However, due to the multidimensionality of productivity, the interpretation of the term is not only specific to the input and output, but it also has a level-specific interpretation. This means that to analyze productivity, both the input and output terms must be defined as well as the level in which the system is analyzed. The input variable, which is the resources that are needed to produce the product, can vary in type, for example, labor, capital, material, or energy. Depending on the system to be analyzed, either partial or total productivity can be assessed where partial productivity takes into account a subset of the inputs, whereas total productivity considers all inputs (Hannula, 1999).

On the other hand, the output only refers to the product produced. The variables on both output and input have a different unit of measurements and therefore, must be normalized to allow the aggregation of variables. This is why even though the concept of productivity relates to physical phenomena, productivity is expressed in monetary, labor, or physical units with the goals of making the variables interoperable (Broman, 2004). Regarding the level specificity Gerwin (1987) gives examples of the different levels a manufacturing company can assess productivity on, which are; the individual machine or manufacturing system; the manufacturing function, for example assembly; the manufacturing process for a single product or group of related products; the factory; and the company's entire factory system.

For this research and based on the client's statement, this study will focus on labor productivity based on value-added. According to Attar, Gupta and Desai (2015) labor productivity based on value-added assesses the productivity of the workforce, where the input and output are measured in labor units which, in this case, is in hours. The input is the total hours spent on the task, and the output is the total productive hours gained or total hours that attribute to value-added. As labor productivity is measured at the level of the workforce, it will not be representative of the general productivity of the turnaround, as the general productivity of turnaround is influenced by many factors.

3.2.5. Time on Tools

Now that a definition of productivity and a focus on labor productivity has been established it is now relevant to introduce the term Time on tools. Time on tools is a measurement that describes workforce utilization. Essentially, time on tools measures the ratio between productive time and the total duration of the task. According to Steinhubl, van Leeuwen, and Rogers (2009), time on tools or wrench time is the ratio of time spent on value-added work. In other words, the average time that a craftsman spends directly working to execute construction, maintenance, or shutdown activities.

According to the client, BPRR, Time-on-Tools is a statistical method for the systematic study of events — i.e., the occurrences that are observed, described and recorded during the study of the working process (e.g., worker present, worker absent, among others). With time on tools, it is of particular relevance, whether such events, contribute directly (value-creating), indirectly (non-value-creating) to the progress of work or, are disruptions, i.e., interruptions of the working process. The gathered statistical data provides valuable indicators for improving, the working processes, and therefore improving the productivity levels achieved.

The reason for using time on tools to measure labor productivity is because time on tools only considers workforce by itself and leaves out any other sources of unproductivity that are not directly caused by the workforce. Time on tools analysis makes a differentiation between actual time on tools, time on supporting activities, and time wasted. Actual time on tools only considers direct work in terms of time without regarding time spent on supporting activities like required travel, obtaining and preparing tools, parts, or instructions. These supporting activities are activities that must be done in order to accomplish the task but do not contribute to the value-added by the task.

Jayakumar (2018) in his research on turnaround productivity differentiates the different categories as follows; The category Time on tools refers to the direct work that involves all time spent on manual labor that directly adds value to the culmination of the task. The category

Indirectly Productive activities refer to all the time spent on activities that enable the worker to execute the task. In other words, all unavoidable time spent preparing for the execution of the task. These activities can be, for example, preparatory work like receiving instructions, preparing the workspace. It can also be related to material or tool handling and preparation like transporting to the work location. The Unproductive activities category refers to all activities that do not contribute, in any way, to the task at hand. Jayakumar (2018) makes a distinction between avoidable unproductive time and unavoidable unproductive time. Unavoidable unproductive activities are all the activities that do not add value to the task and are part of the human factor of working. In other words, all time lost due to personal breaks like bathroom breaks, and lunch breaks. The avoidable unproductive activities refer to all-time spent that does not add value to the task that cannot be considered as personal time. These activities can be waiting for the permits, material, contractors, and instructions, among others. Other avoidable unproductive activities are those tasks that were not executed correctly and require reworks.

Because of this categorization of time use, Time on Tool analysis provides reasonable indications on how efficiently time is spent by the workforce. By differentiating between time on tools, indirectly productive time and unproductive time, strategies can be made in order to tackle the specific sources of wasted time by the workforce. This will maximize time on tools which will have a positive effect on productivity.

3.3.Nature of Clients Problem

This subchapter is a literature review that focuses on finding the root or nature of the client's problem statement. The goal of this subchapter is to prove whether or not there is enough supporting evidence on the relevance of the client's problem statement on a general industry level. By shedding light on the industries gap, this literature review will prove that research is relevant not only for the client but for the industry in general. Initially, the literature will expose to the relevance and importance of turnarounds for the oil and gas industry. Subsequently, an analysis of the complexities that characterize turnarounds will be provided. After which the importance of Organization, Coordination, and Communication for the successful execution of turnarounds will be presented. Which will be Followed by the importance of labor productivity during the execution of turnarounds. The subchapter will then analyze the drawbacks of project management tools commonly used in turnaround projects. The subchapter will culminate with a section dedicated to the integration of Schedule, labor, and geospatial data. This last section can be seen as the conclusions for this chapter and provide the theoretical benefits of integrating Schedule, labor, and geospatial data for turnaround projects.

3.3.1. Relevance of Turnarounds to the Industry

The aspect of turnaround that makes them so crucial to the different industries is their direct effect on the companies' competitiveness and profitability. First, because turnarounds maximize production, capacity, and ensure that equipment is reliable and safe to operate. And secondly, because Plant turnarounds constitute the single most significant identifiable maintenance expense in terms of direct costs and lost production (2009, Ben-Daya, M. & Duffuaa, S.O.). The loss in production refers to the downtime the unit has to endure while the turnaround is in the execution phase. For this reason, turnaround projects are strategically planned to last as short as possible with the goal of reducing the production loss as much as possible while still assuring the desired levels of quality and reliability of the unit. Because of these characteristics, Duffuaa and Raouf (2015) argue that the successful accomplishment of this event in terms of quality and cost is vital to the profitability of the company and its competitive advantage. Similarly, Ben Daya et al. (2009) show in their research that, even though turnarounds can cause a production plant availability reduction of about 2–3 % every year, its economic benefits, due to a reduction in equipment failures, can increase the firm profits up to 15 %.

According to Abbas & Manarvi (2011) turnarounds are specially critical in the oil business as, due to volatile environment and dynamic market that characterize the industry, companies are even more reliant on reducing production loss and on looking for new ways to improve efficiency and productivity which in the end will define the refineries level of competitiveness. For this reason, turnarounds represent the most critical and expensive maintenance task for the industry (2009, Ben-Daya, M. & Duffuaa, S.O.). Not only does the market make turnarounds more critical event for the petrochemical industries but also the complex nature of oil refineries makes the challenge even harder due to the highly critical nature of the refining process that cannot afford unexpected failures (Telford et al. 2011). Now that the importance of turnarounds to the industry is exposed. It is now relevant to dig into the complexities that characterize turnaround projects and make them so unique.

3.3.2. Complexities that characterize turnarounds

As previously expressed, oil refineries usually are composed of different functional units that vary in their function in the refining process. Because of this, turnarounds vary depending on the type of unit to be maintained. Regardless of the differences, some characteristics entail most refinery turnaround projects. To grasp the uniqueness and complexity of turnarounds, this section will be dedicated to present the complexities that characterize turnarounds. These findings will be based on an extensive literature review and will serve as a starting point to comprehend the origin of the client's problem statement.

High internal strategic pressure

Initially, the company high internal strategic pressure will be discussed. This high internal strategic pressure can be linked to the relevance to the industry touched in chapter 2.1.2, where the importance of turnarounds for the business and their direct effect on the companies' competitiveness and profitability is highlighted. Basically, turnarounds are essential because they maximize production capacity and ensure that equipment is reliable and safe to operate. Also, plant turnarounds constitute the single largest identifiable maintenance expense in terms of direct costs and lost production (2009, Ben-Daya, M. & Duffuaa, S.O.). The loss in production refers to the downtime the unit has to endure whilst the turnaround is being executed. For this reason, turnaround projects are strategically planned to last as short as possible with the goal of reducing the production loss as much as possible whilst still assuring the desired levels of quality and reliability of the unit. Because of these characteristics, Duffuaa and Raouf (2015) argue that the successful accomplishment of this event in terms of quality and cost is vital to the profitability of the company and its competitive advantage. Similarly, Ben Daya el al (2009) show in their research that even though turnarounds can cause a production plant availability reduction of about 2–3 % on a yearly basis and its economic benefits due to the reduction in equipment failures can increase the firm profits, due to the minor loss production, up to 15 %. This then evidences the importance of turnaround project and the consequent reason for the high internal strategic pressure from the company to successfully execute the turnaround.

Schedule drive & project duration

This high internal strategic pressure has repercussion on what drives the turnaround management. The internal strategic pressure and the effect the downtime duration has on the overall business of the refinery, make turnarounds highly schedule driven and a drive to make the turnaround as reduced in duration as possible without disregarding safety and quality. Bevilacqua et al. (2011) evidence this when he states that, due to the weight of production losses, turnarounds are tightly scheduled in 4- 5 weeks with the goal of reducing the amount of downtime of the unit at work and therefore reducing the production loss as much as possible. The high schedule drive is also appreciated in Al-Turki et al. (2014) study where they argue that If the planned execution period extends to the turnaround will cause a large amount of unplanned production loss, which will affect the project feasibility.

Size of the project & Number of goals and tasks

Not only is the project highly schedule driven with high internal strategic pressure, but the size of turnaround projects is also a characteristic that attributes to the overall complexity of the project. Turnarounds are characterized by having a high number of project goals. The main objective and underlying objectives as exposed in the turnaround introductory chapter can be translated into the variety of different goals which the turnaround scope can uptake. Taking into account the definition of integrated turnarounds exposed in chapter 2.1.2., it is clear that turnaround projects are not only focused on the maintenance of the unit. Turnaround's scope rather entails a mix of maintenance tasks and project work which goal is to fulfill a mix of the underlying goals exposed in the turnaround introductory chapter. These Goals are generated from various sources such as statutory safety requirements, production, or quality improvement programs (M. Ben-Daya & S.O. Duffuaa, 2009). These underlying goals are, of course, not fixed, and the level to which these objectives are fulfilled varies depending on the specific scope of the turnaround.

Variety in task type & technical disciplines

As described in the chapter introducing turnarounds, refineries are composed of different units which are then composed of a large number of specific components. Because of the variety and specificity of the type and needs of these components, turnarounds adopt, not only a high number of tasks but a wide variety in task types. Essentially the wide variety of tasks are required because of the different functional disciplines and specialized skills required to execute the turnaround successfully. Then it can be said that the variety in tasks is a result of the varied type of assets that compose the refinery unit and the different type of work they require. As a consequence of the varied type of tasks, there is a need for the involvement of different technical disciplines. Turnaround tasks usually include mechanical, electrical, instrumentation, piping, rotating, inspections, scaffolding, and other specific types of works.

Size of project team

As previously mentioned, turnarounds are characterized by requiring particular but varied types of resources and skills in significant quantities. Due to the size of turnaround projects, they usually require significant human, materials, technical, and economic resources to successfully execute the turnaround (2011, Bevilacqua, et al.). Regarding human resources, in their study, Bevilacqua et al. (2011), expose that turnaround involves as many as 1500–2000, skilled contractor workers brought on-site to perform a conglomerate of interrelated jobs. Similarly, M. Ben-Daya, & S.O. Duffuaa (2009) exposes that the size of the workforce needed in some circumstances exceeds 15 times the size of the regular in-house maintenance personnel that proves the great resource and skill requirements of turnarounds. Al-Turnik et al. (2014) add to this argument by stating that turnaround projects are short in duration but high in working load intensity as they fit as many as 300,000 manhours in a span of 4 to 5 weeks. This makes it very difficult for the owner of the refinery to cover the complete scope with the in-house personnel and therefore, must look to the market in order to fill the gap.

Reliance on external stakeholders

Looking towards the labor market to fill the skill and workforce gap has repercussions that contribute to the complexity of turnarounds. It is incredibly tough to find in the market a contractor that covers the highly specific and varied skills and services that are required for the turnaround project. Therefore, the owner must assign different contracts to specific contractors for scope in their specific field. This increases complexity because it will require extra efforts to manage such a quantity of different contracts and will also increase the number and dependency on external stakeholders. Al-Turki et al. (2014) agree when he argues that the success of the project depends highly on suppliers and contractors as they provide the materials, resources, technology, and services that the project requires an owner is not able to cover. These buy decisions have repercussions on the way turnarounds are managed as by incrementing the dependency on external stakeholders the owner loses direct control over the turnaround and therefore must occur to extra efforts to assure the contractor meets the quality, safety and schedule goals set. Turnaround demand on labor resource is so specific and to such an extent that it inherently depends on and affects the market's supply for labor resources which will again have repercussions on the quality of labor acquired (2011, Bevilacqua, et al.).

Lack of trust and experience with involved parties

The high reliance on external stakeholders and the market conditions have repercussion on the complexity of turnaround projects. As previously mentioned, Turnarounds require specific skills, expertise, and services that it would be very costly for the owner to provide by themselves. Therefore, given the size of the scope and the variety of different disciplines, skills, and services required a large part of the scope must be outsourced to different contractors. The problem with refinery turnarounds is that they usually operate following strict regulations and processes that the contractors are obliged to follow. Because of the amount of specific personnel needed to cover the scope and needs of the turnaround is so large that Ben-Daya & Duffuaa (2009) and Shaligram Pokharel & Jianxin Jiao (2008) agree that the number of contracting parties is generally high, and most of the workers belonging to the contractors are new to the site. They also agree that contractors come from organizations with different cultures and attitudes towards safety, which will make collaboration complicated and will require important control efforts from the owner's behalf.

Dependencies between tasks

The outsourcing of a significant part of the scope to different contractors also requires special attention on behalf of the owner on the integration of operations and tasks. This is mainly because there are dependencies between tasks and interfaces between the different disciplines. The dependencies between tasks are present because the tasks follow a precise logical procedure of inspection, repair, replace, or overhaul. The dependencies are also affected by the different variety of tasks, their granularity, and the control of common work processes in the industry. For these reasons, it is prevalent that tasks in turnarounds have a start to finish relationship, making the possibilities of parallel execution of tasks difficult and makes handovers a critical aspect of turnarounds.

Interfaces between disciplines

The conjunction between the high variety of tasks, the high involvement of different technical disciplines, and the high dependencies between tasks already give hints of the complexity of interfaces in turnarounds. The characteristic of turnaround that most attributes to this complexity is the actual technical complexity of the refining process and the technical complexity of the elements that compose the refining units that require a myriad of interrelated jobs and specific expertise. For example, disciplines present in turnarounds can be process engineers, mechanical engineers, environmental engineers, structural engineers, among others, which are responsible for monitoring, repair, and maintenance of equipment in the respective defined areas (2011, Bevilacqua, et al.). Efforts must then be made to align the different discipline requirements in order to assure correct execution of the turnaround and consequently proper operation of the unit afterward.

Scope Uncertainty

Besides turnaround scope being defined by various goals and a wide variety of tasks. The scope itself in turnarounds is never straight forward. This is because turnaround projects have a blind spot caused by the uncertainty on the state of wear and damage to the equipment inside the unit (M. Ben-Daya & S.O. Duffuaa, 2009). Of course, refineries have many different measures and calculations on the maintenance needs of their assets and conduct inspections to corroborate that data, but there are equipment and parts that are unreachable whilst the plant is running. This means that there are uncertainties on the state of the internal equipment, therefore, uncertainties on the scope of turnarounds. Once the shutdown has initiated, and inspections begin, it is common to see the scope of the turnaround increase, making turnarounds highly dynamic in scope. D. Emiris (2014) argues that one of the most representative problems in turnaround projects is the changing project scope as cases show that the uncertainty in scope and the lack of preparation towards it can result in scope doubling. The increasing uncontrolled scope could prolong critical activities, thereby causing substantial productivity losses to the company (Shaligram Pokharel & Jianxin Jiao, 2008).

Lack of HSSE Awareness

Execution of turnarounds can be a major source of health and occupational hazards if not performed with appropriate safety measures. Refineries run with materials at high temperatures and high pressures, and some of the materials themselves are caustic or toxic and must be handled appropriately (2011, Bevilacqua, et al.). Hazards during turnarounds can be physical, chemical, and psychosocial hazards as workers are frequently exposed to excessive noise, vibrations, dangerous chemicals, and uncomfortable or extreme environmental conditions (2014, Al-Turki et al.). Typical accidents caused by these hazardous conditions are crushing by moving machinery, unexpected start-up, falls from height, accidents involving falling objects, electrocution, electrical shocks, burns, confined spaces, asphyxiation, explosion, fire, and gas leaks. Proving that HSSE awareness is a major concern when implementing refinery turnarounds especially as in many cases tasks are subcontracted and hence involves workers who might not be familiar with the machinery and the place or might not have the adequate training (2014, Al-Turki et al.). HSSE is so important that governments, legislative organization, and even owners themselves regulate and enforce standards for ensuring safety in the working environment (2014, Al-Turki et al.).

Spatial Conflict

Regarding spatial conflict, there are two critical aspects to take into account; the interface with the existing site and clashing tasks. Depending on the turnaround and the refinery, the turnaround scope can entail from one to various units. The complicated aspect comes as turnaround are executed within the refinery, meaning that the project will have interference with the units that fall out of the current turnaround scope. This is extraordinarily complex for refinery turnarounds as the units of the refinery run with materials at high temperatures and high pressures that can be hazardous or toxic. Also, due to the adjacent units, extra effort has to be made to manage traffic plans, and crane position planning for lifting as space will be restricted. The interference with existing units also limits the working space, which will increase complexity on task execution. Not only does the existing site affect the spatial conflict but also clashing activities. The term clashing activities refers to activities that were planned at the same time in the same space, making them overlap and activities that due to the nature of its execution require specific spatial regulations. Examples of activities that require spatial regulations are piping works like grinding and welding, nondestructive testing activities that use x-ray machines or liftings. These activities require spatial regulations as their execution affects the safety of the surrounding environment. Welding and grinding work in refineries must be handled with care as these activities generate sparks or extreme temperature that in combination with the refineries hazardous environment will account for a substantial risk and therefore must be thoroughly managed. In the example of nondestructive tests using x-rays, they require a spatial regulation as x-ray machines emit radiation and can be harmful to the surrounding workers. Also lifting of equipment, materials, or elements contribute to spatial conflict as falling objects represents hazardous situations, and thus spatial conflict is generated by the line of fire created by the lifting object and the personnel working under these lifting activities. Workers are not allowed to be under the line of fire for safety. These are just a few examples of the types of tasks that affect their surroundings and therefore on surrounding activities if not planned and managed correctly.

3.3.3. Importance of Organization, Coordination, and Communication In turnarounds

The previous section described complexities that characterize turnarounds. It is important to point out the predominance of organizational complexities. This predominance is evident when analyzing each complexity individually and seeing how each complexity requires an increased effort from the management team on managing people effectively. This section will then discuss, based on the complexities, why the organization, coordination, and communication are vital for the success of turnarounds.

According to Bakker and de Kleijn (2014), fragmentations are barriers or gaps in the project team created by the different hierarchy levels and the different functions, disciplines, or even teams. Fragmentation occurs when project teams are too big in size or require a wide range of varying disciplines or functions. Making it difficult for project teams to collaborate as these gaps and barriers generate operative islands where the integrity of the team is lost which affects the level to which communication, coordination, and decision-making cascade through all parties and individuals with fluency (2016, Suprapto, M.).

Fragmentation is evident in turnarounds as the complexities that characterize them attribute to a certain degree to this phenomenon. The number of project goals, the variety of tasks and the dependencies between tasks all contribute the fragmentation of turnaround project teams as the project will be fragmented in maintenance scope and the project scope it will also be fragmented in the variety of different tasks that characterize turnarounds as well as the involvement of the different technical disciplines. It is also evident that lack of resource and skills availability, interfaces between different disciplines, the number of contracts, the size of the project team, and lack of trust in contractor all contribute to fragmentation. Lack of resource and skill availability fragments the project team as specific resources, or skills will need to be outsourced, which will require a new contractor and therefore, a new barrier. The lack of experience with parties involved and lack of trust in a contractor, number of contracts and interface between different disciplines describes the phenomenon of fragmentation as there is a difference in working culture, experience, expertise, communication system or project management method each time a part of the project scope is outsourced.

Not only are turnarounds highly fragmented, but they are also dynamic in scope and fast-paced as previously explained. This adds up to a more considerable effort from the management team to coordinate the involved stakeholders and to make sure that communication on scope changes cascade through all involved stakeholders effectively and within a short time frame to prevent clashes or wrong execution of work. With the relation between complexities made and agreeing with Smith and Parker (2008) study, it is clear that turnaround management requires an important focus on organizational dynamics, more specifically coordination and communication. Similarly, in a benchmarking study for more than 200 turnarounds, Joshi (2004), argues that most turnarounds experience schedule slips and costs overruns, which are caused by inadequate planning and coordination. According to an article published by consulting giants McKinsey & Company (2015) a variety of factors account for this poor performance in execution of construction work, which is caused by poor organization, Inadequate communication, flawed performance management, contractual misunderstandings, missed connections, poor short-term planning, Insufficient risk management, limited talent management. Even though McKinsey & Company (2015) article is on the construction industry in general, it can be argued that the type of work performed in turnarounds and how they are managed is to a certain extent similar and therefore comparable.

To sum up this subchapter a list of factors proving why the organization, coordination, and communication are essential to turnaround management:

- A large number of parties involved leads to substantial barriers, caused by fragmentation, which impedes essential communication and cooperation.
- The tendency for individual members of a group to become increasingly less productive as the size of their group increases as a result of a loss of motivation and coordination problems.
- Wide variety and number of tasks to be executed during turnarounds leads to lack of awareness of event and causality, which affects speediness in decision making and early problem recognition.
- Amount of detailed data surrounding the turnaround is tremendous, which will affect interpretability and accessibility caused by an overload of information.
- Dynamic nature of scope in turnarounds affects coordination and demands efficient and speedy communication assuring information cascades through all relevant personnel.

3.3.4. Importance of labor productivity In Turnarounds

The previous chapters show how relevant these major maintenance projects are to the oil and gas industry. Because of this importance and the implications, it has on the project like high internal strategic pressure, the high schedule drive, and the high reliance on external stakeholder, turnarounds become very critical in the execution phase. In his research, on turnaround productivity, Jayakumar (2018) argues that, even though many factors influence the turnaround productivity overall, it is the workforce productivity the essential driver that lead to turnaround success. If a turnaround is not executed correctly, the time lapse between turnarounds may be shortened, affecting the overall competitive edge of the refinery (Hey, 2017). Raoufi and Fayek (2014) argue that the high demands on energy and the volatility of the oil and gas industry, will put more and more pressure on the execution phase of the turnaround which will require the implementation of any possible strategy to maximize productivity in this phase and on the turnaround overall.

Similarly, Steinhubl, Van Leeuwen, and Rogers (2009) argue that companies in the energy sector are under intense pressure to reduce costs, and regardless of this, they argue that the oil and gas industry has still significant opportunities to achieve this by increasing worker productivity. Hwang et al. (2018) align with the desires from the client to achieve business sustainability through productivity when they argue that improving labor productivity is vital for the sustainable development of the oil and gas industry. This conglomerate of researches proves the existing drive on an industry level to maximize labor productivity, especially in turnarounds as they are an important factor in the business sustainability for the downstream sector.

3.3.5. Information Communication Technologies

Golzarpoor et al. (2018) considered information communication technologies as indispensable for project success because the different type of information systems like document management systems, collaboration management systems, workflow management systems, and advances project management systems are used to tackle a wide set of complexities found in projects. These technologies play an important role in large scale projects as the amount of data relevant to the project is abundant (Redwood et al. 2017). This is even more accentuated in turnarounds because of the high number of project stakeholders and the massive amount of information exchange during the different phases of the turnaround. The problem with these integrated technologies, according to Panetto and Cecil (2013), is that they are usually organization based, meaning that different organization use different information systems. The problem does not only lie with the use of different systems but due to the high flexibility of modern systems were the providers designs the functions based on the client needs meaning that two independent organizations might be using the same system but operation wise they are not relatable.

Cormier and Gillard (2009) argue that for turnarounds, the implementation of a structured knowledge transfer system can improve the success of any turnaround drastically. In their research, they argue that by implementing such a system that assures that information cascades through the multitude of parties involved in turnarounds, there is an improvement in the consensus of information available which enhances coordination. Bansal (2012), argues that as fragmentation is an inherent characteristic of the construction industry, which calls upon the need for the proper implementation of information communication technologies. Cormier and Gillard (2009) argue that due the intensified fragmentation experienced in turnaround projects; the implemented information system should not only consider the needs of the owner but also the destination audience which varies widely in terms of craft, experience, and level of responsibility. This is an important factor to take into account the future development of the visualization tool. For this reason, when considering the selection of the visualization means, the system should be able to provide seamless information flow and should be made in such a user-friendly manner that it is, in fact, comprehensible by the wide variety of stakeholder involved in turnarounds.

3.3.6. Drawbacks of Project Management Tools

In this section, project management tools used in turnarounds will be discussed. Regardless of the uniqueness of turnarounds, the tools used to manage these projects are the same as tools used in the construction industry. The tools to be analyzed are scheduling tools and CAD tools.

Scheduling tools

In the last decades, different methods and computer-assisted tools have been developed to help the construction industry gather, simplify, visualize, and analyze data. Planning & scheduling, and computer-aided design software's have had a significant impact on the construction industry. Planning and scheduling software's such as Primavera and Microsoft Projects are available and widely used in the construction industry (2004, Chau, K.W., Anson, M., & Zhang, J.P.). These software's arrange a set of tasks into a sequential order depending on the relational nature between tasks. Once data is imputed, and relations are defined, the software analyzes data and presents the construction schedule graphically in the form of Gantt-charts or PERT diagrams. These software's permit users to visualize the schedule for the construction project abstractly and therefore helps schedulers have a better interpretation of the schedule allowing them to analyze and optimize the schedule in a more user-friendly manner (2017, PMBOK Guide).

Even though these software have been widely used in the construction industry, they do have pitfalls. Researchers, Chau, Anson, and Zhang, (2004), Koo and Fischer (2000), and Bansal and Pal (2008) point out certain pitfalls for the usage of this software. The following drawbacks were found;

- When generating the schedule, the data that is relevant to the project and the building of the schedule is abundant and therefore, challenging to manage and visualize. This information, which includes, constructability conflicts, resource and equipment allocation, time and space conflicts at the site, time cost trade-offs, among others, makes it very hard to display all this information in PERT diagrams or Gant charts.
- Even though so much input is required for the correct construction of the schedule, the final schedule does not show the thought process or logic behind on schedule. Therefore, leaving out relevant information for schedule analysis and optimization, as well as decreasing the interpretability of schedule.
- The lack of consistency in these schedules is problematic mainly because project team members who were not involved in the construction of the schedule have to interpret and implement the schedule. This problem is even more drastic when subcontractors and vendors, belonging to different organizations, must interpret and implement the schedule.
- Another significant drawback of these tools is that schedules do not have spatial features. Spatial features Given that schedules rely heavily on the design of the structure and the site layout, the fact that they lack spatial features leaves planners with a particular grey area where they have to rely on design documents, their judgment, and experience to develop the schedule.

All these drawbacks make it very difficult to interpret the schedule and cause actual problems in the schedule to be only evidenced during the execution of the tasks. These drawbacks are even more critical for turnaround projects as the amount of interrelated data is much higher. This then requires increased efforts to construct the schedule and consequently, due to the abundance of information, makes data less interpretable by stakeholders who are not involved in the construction of the schedule itself.

Computer-aided drawings (CAD) & Building Information Modelling (BIM)

The other computational tools that have been developed in recent years has been Computer-aided drawings (CAD). Traditionally construction plots where 2-dimensional layouts of the structure of the building. The complete design of the structure consisted of multiple plots that can be layered one on top of the other to form the complete design of the structure. These plots were usually not integrated, meaning that each layer of the design has no explicit relation between them other than the relation the designer has assigned. This generated the need for designers to pay special attention to interfaces between plots, as errors from one plot to the other are difficult to point out. Given these restrictions, the industry needed to tackle the interface problem by generating integrated models. The industry responded by shifting from 2D to 3D models. This shift represented a great strategy to tackle integrity of the module, allowing designers to work under one model and allowing them to visualize clashes and errors in the model (2014, Chau, Anson & Zhang). However, 3D models are inherently used for the design phase leaving no direct use for project management. This is because 3D models display the final design of the project, rather than the status of the project at a particular time, giving it little assistance to project control. This is because there is no integration between the 3D model, schedule, and other data.

To tackle this lack of integration between 3D model, schedule, and relevant data, the industry has responded with the development of building information modeling (BIM). BIM is an object-oriented tool that integrates the 3D model with the schedule and other relevant data. This is done because BIM software allow specific information to be assigned to the different elements that compose the model. The type of data that can be assigned to each element varied widely, for example, material and mechanical properties of the element, scheduled construction time of the element, cost of the element, resources allocated to the element, among others (2008, Bansal & Pal). With this information integrated into the 3D model, BIM has a wide range of applications and analysis tools supporting the design and construction through its phases. These applications are 4D simulations, HVAC heat flow, building acoustics, structural analysis, cash flows, clash detections, among others.

Focusing on the planning, cost, and construction sequence of projects, the 4D simulation tool is one of the most used applications of BIM. 4D simulations integrate static 3D models with their respective schedule, taking time as the 4th dimension and representing the construction sequence of the project. By integrating both aspects, construction managers or schedulers can virtually visualize the day to day development of the project as planned. 4D simulations allow construction planners to evaluate the original schedule by detecting schedule conflicts, time-space conflicts, constraints, and evaluating different construction methods (2002, Akinci et al.). By applying these analyses, planners can generate different scenarios to develop a more realistic schedule for the project as well as having different scheduled scenarios in order to choose the best alternative. Besides evaluating and correcting the schedule, 4D models open up a range of analysis that can be implemented based on the model. Regardless of the benefits of BIM tools, they are still object-oriented and do not provide information on the labor distribution and spatial conflicts caused by the workforce rather than the structural element. This will then have drawbacks on analyzing conflicting simultaneous operations that rather than relying on the structural element rely on the assigned labor resource's workspace, which is a critical aspect of turnarounds. Also given that tasks are assigned to elements in turnaround projects, the level of detail required to implement a 4D simulation fully will require a highly detailed model of the refinery units. Given the complexity of these units and the vast amounts of elements that compose these units, it is quite difficult and costly to obtain such a detailed model that is required to fully implement a 4D simulation to the level of detail to which tasks are assigned to elements.

3.3.7. Integration of Schedule, Labor and Geospatial Data

Up till now, in the literature review, it has been made evident that turnarounds are highly sophisticated in the organizational aspect that causes turnarounds to be highly fragmented. Also, it has been made evident that turnarounds are characterized by having a dynamic scope due to emergent work. Because of the high internal pressure turnarounds are required to deal with problems that arise from this dynamic scope and fragmentation within a short time frame. Especially because of the fragmentation caused by the amount of work outsourced, which increases the risk of the owner, strict control strategies during the execution phase of the turnaround have to be implemented. The literature review shows that information communication technologies provide enhanced communication and coordination, and because current PM tools used in turnarounds have drawbacks that are not maximizing awareness during the execution phase, it can be argued that the implementation of a new information communication technology that fills these gaps will benefit the turnaround.

Based on these points and researchers opinion on developments like Bansal and Pal (2008) that argue that further developments need to be implemented in certain aspects such as resource allocation, and Chau, Anson, and Zhang (2005) that argue that there is a need for the use of 4D tools to incorporate other construction aspects, such as resource management and cost assessment. It can be argued that the integration of schedule, labor, and geospatial data in a 4D visualization allows better interpretation of the order and distribution of the resources needed at a specific point and time during the execution phase. With the tool managers, supervisors, and relevant stakeholders have a way to analyze the distribution of labor in turnaround and with this information be able to have better coordination as information is more accessible and easier to interpret. Also, with this information, health regulations can be better adjusted as the information shows in which geospatial location most work is accumulated and therefore, more risk concerning health and safety. It also allows better resource management as a simple visualization allows better interpretations and better strategies when leveling resources. All these qualities that the visualization of resources brings will improve the interpretability of the schedule and workflow, as well as improving coordination, and decision making through execution phases of the turnaround, which can have a positive impact on productivity.

4. Conceptual Design

According to the Dym & Little cycle, the conceptual design stage consists of establishing preliminary design specifications, requirements and functions set by the client, assess restrictions, choose an ideal visualization mean and generates conceptual design alternatives. As a starting point for the Conceptual design, the research will take the preliminary requirements set by the client. With this information, the research will analyze the restrictions set by the client's current state. Subsequently, a literature review will be conducted on the ideal technology medium or platform that covers the design need set by the preliminary requirements, and that has been proven to be useful for the needs of the client. With the platform chosen, the research will then look to consider different design alternatives focusing only on the preliminary requirements and the capabilities of the platform chosen. This chapter will then be divided into four subchapters. An initial subchapter, describing the initial POC requirements set by the client. Followed by a subchapter dedicated to the Information flow in a turnaround in order to understand data origin and current state of the client's data flow, which will influence the visualization means selection. Subsequently, a literature review will be done on the visualization technology chosen more specifically on the applications of the technology in similar situations in order to grasp on whether the chosen technology is, in fact, fit for purpose. From there a visualization mean will be set an introduced. The chapter will end by fixing a conceptual design based on the capabilities of the chosen design mean and the requirements from the client.

4.1. Initial POC Requirements

The client's statement proposes an innovative tool that integrates labor, schedule, and geospatial data where users can easily comprehend and visualize the information needed to execute turnaround tasks. The initial concept of the visualization is the integration of geospatial references with labor resources and schedule. The geospatial reference would be the 2D plot of the refinery in the x and y coordinates. A third dimension will be represented in the z coordinate. This third dimension will be the labor resources represented in working hours and will be visualized as bar graphs. The fourth dimension of the visualization tool will be brought by the time element in the schedule and will be representing the changes in time. These four dimensions are represented in figure 2.

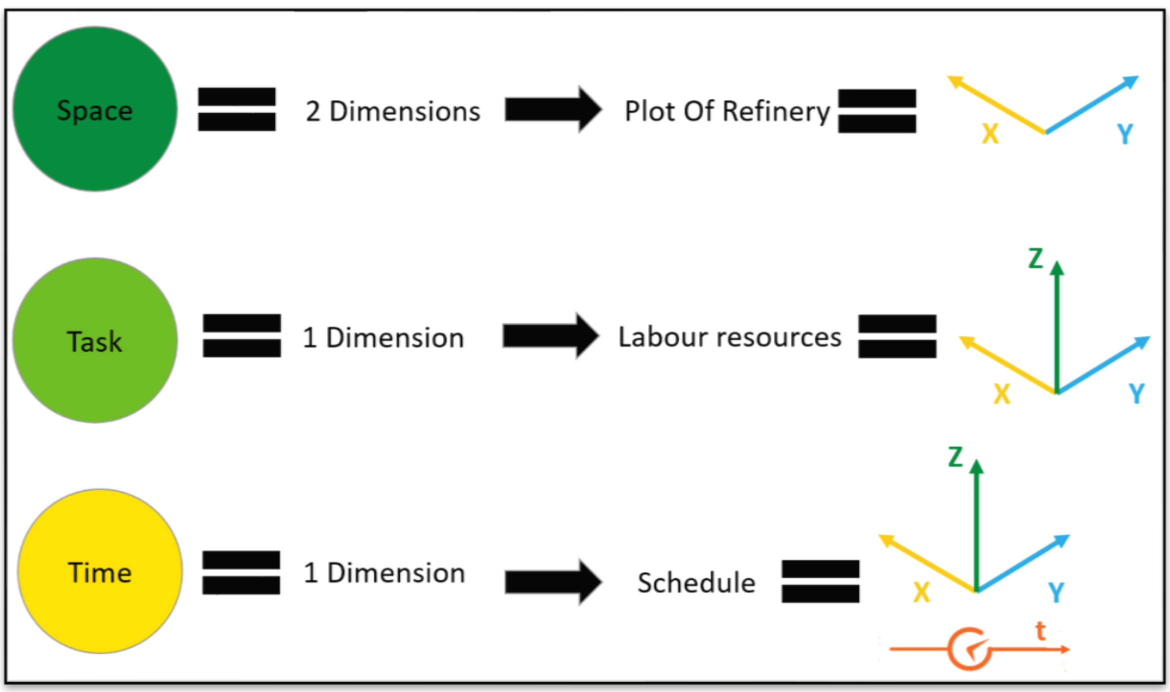

Figure 2: Representation of the four dimenasions of the visualization tool

The bar graphs representing the labor resources are an indicator of where work is required and helps visualize the amount of work needed in a specific point of the refinery. The client has also required bar graphs to differentiate between the different disciplines present in the turnarounds (Mechanical, Cat/Cleaning, Piping, Elect/Instr, Rotating, Inspection, Scaffolding, Support) in multicolor scales. The multicolor differentiation can be appreciated in the initial proof of concept found in Appendix A.

The client has also required for the visualization tool to be interactive in a 3D environment meaning that users should be able to scroll, zoom, pan out, select elements, retrieve relevant information and be able to navigate through time. All these specified functions must be included in the visualization tool to fit the client’s desires and will have an influence on the selection of the visualization means.

Due to the characteristic of turnarounds, the schedule is off course set to change during the turnaround due to the scope uncertainties were tasks may be delayed, completed or new scope may arise. This generates the need for an integrated flow of information as there is a need to visualize the real-time state of the project. The client has expressed that reports of the actualized data during the execution are updated twice a day during the execution phase of the turnaround. Therefore, it has been set that the visualized scene should be actualized with each data actualization, meaning that the scene that the data will visualize should be up to date for each day. The result will be an interactive and dynamic visualization tool that shows the allocated labor resources represented in working hours of the different disciplines with the geographic reference of where those working hours must be spent over time.

4.2. Data Sources, Interfaces and Availability

Before diving into the selection of the design means it is first relevant to analyze the data sources, the interfaces between the different data sources, and the level of data availability required for the visualization tool. This is crucial for the conceptual design as the data sources interoperability will restrict or enable different design means and possibilities, and the availability of data will decide if data enhancement is required for the visualization tool. Appendix B shows the conceptual flow of information delimitating the different applications and software used for TAR2019. As the visualization tool is only interested in the schedule, labor resources, and geospatial data, the analysis will be done on the Roser Suit, and the Primavera P6 Enterprise Project Portfolio Management Suit which are information systems used by the client which contain the data relevant to the visualization tool. This subchapter will then introduce both suits focusing on their functionality and their interoperability possibilities. Subsequently, an analysis will be done on the specific interaction between Primavera P6 and Roser for the TAR2019. This interaction is represented in the delimited system "Execution: Update project, Handover and Commissioning" as appreciated in the bottom left corner of the diagram shown in Appendix B. This interaction analysis will set some restrictions on the selection of the design mean, because as part of the Initial POC requirements from the client is that the visualization tool shows the current state of the turnaround or is at least up to date with the general bi-daily updates. This requires data interfaces to be taken into account to promote an integrated flow of information and prevent information loss between software or application interfaces. From the interaction analysis, the availability of the required data for the visualization will be evaluated.

4.2.1. Primavera P6 Enterprise Project Portfolio Management Suit

Primavera P6 Enterprise Project Portfolio Management is an integrated suite for project portfolio management developed by Oracle, that consists of different applications, functions, and databases. The suite provides role-based functionality to match each project member's needs and responsibilities. According to Oracle's Primavera P6 EPPM manual (2014), the functionalities of the suite are; the administration of enterprise data, optimization of project management and resource management, documentation management, workflow management, report generation, planning and scheduling, and progress reporting. With these functionalities, Primavera P6 EPPM looks to provide a real-time representation of the organization´s projects performance, equips project practitioners with a tool that enables effective planning and scheduling of the projects through its different phases, and provides a medium that analyses, records and communicates reliable data which enhances project control. A flow diagram representing the array of different applications, function, and databases that Primavera P6 EPPM uses is presented in figure 3.

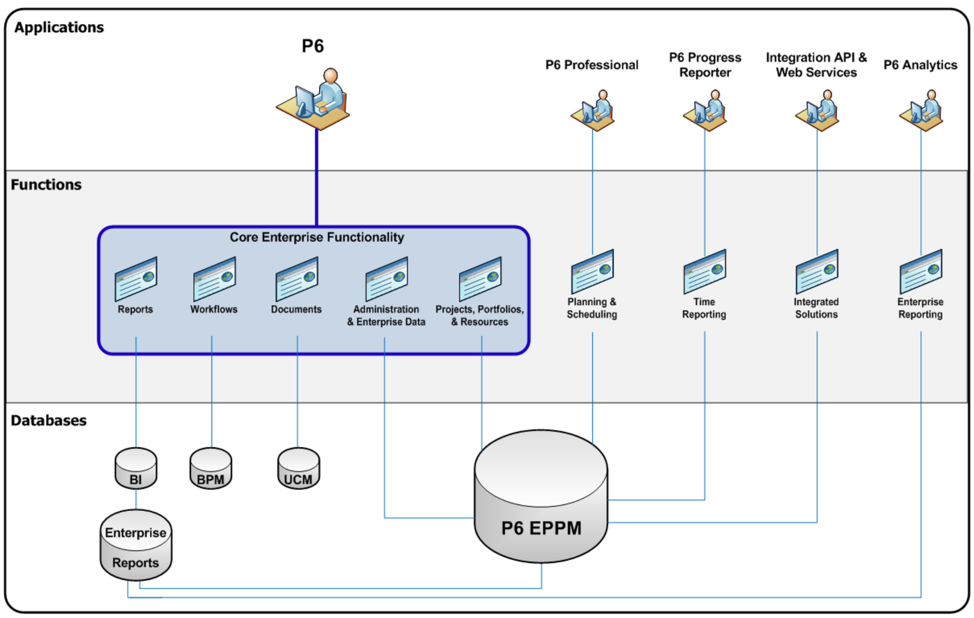

Figure 3 Primavera P6 EPPM Flow Daiagram

Primavera P6 is a web application that serves as the primary interface for administrating and managing projects. The web application provides the project team access to the project information through a flexible interface that allows users to consume and interact with role-specific information provided by the designed interface that best accommodates their function and line of work.

On the other hand, Primavera P6 professional is a desktop software that includes robust planning and scheduling functionalities. This software, as a schedule and planning tool, assigns the time component of tasks taking into account time constraints and interaction between the various tasks that compose the project. Thanks to this time component and additional integrated features like work breakdown structures, organizational breakdown structure, costs, resource administration and assignment, users have the possibility of creating, optimizing, and controlling complex schedules.

4.2.2. Roser Suit

Roser Suite is an integrated database management system (DBMS) for the preparation, planning, and execution of turnaround and plant maintenance projects developed by Roser Consys B.V. The Roser Suit consists of a collection of 12 different applications and functions that are integrated into the same software and are connected through a central database. The different applications are Scope-IT, Systems-IT, Schedule-IT, Blind-IT, Weld-IT, View-IT, Permit-IT, Supply-IT, Bid-IT, Exchange-IT, Catalog, and Change-IT. The Roser Suit looks to cover many of the specific data management needs specific to turnaround and maintenance project with the goal of providing an all in one conglomerate of tools for controlling and optimizing the safety, quality, efficiency, and costs for these projects. The 12 Roser applications have specific functionalities with a versatile capability where each application can be used together separately or in combination with other systems in order to fit the needs of the client. Figure 4 shows how the 12 Roser application can be integrated into the different phases of the turnaround project. The two Roser applications relevant to the execution phase of the turnaround, according to the information workflow for TAR2019 found in Appendix B, will be introduced.

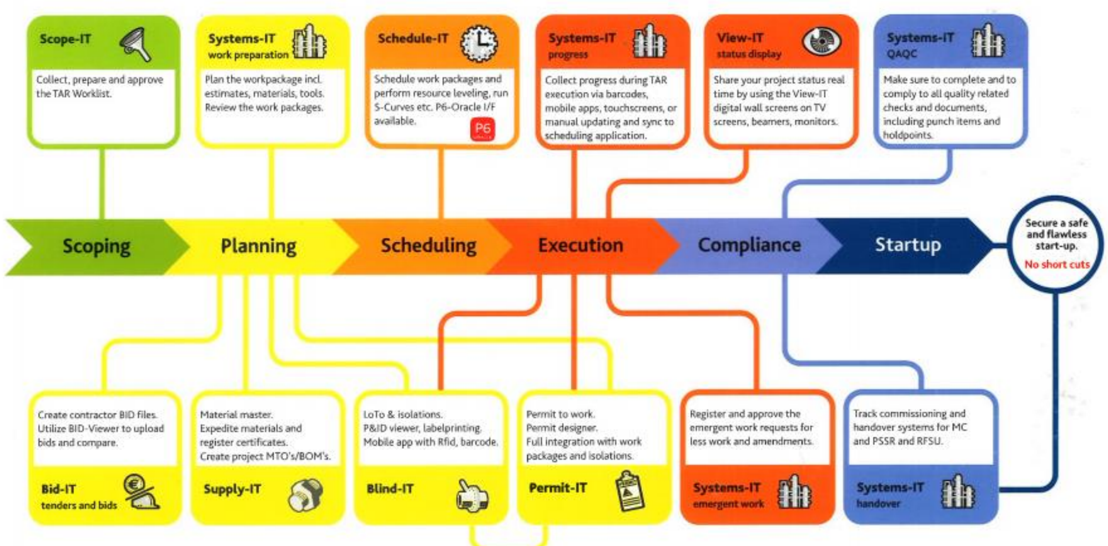

Figure 4: Integration of Roser Applications into different phases of the turnaround project

Scope-IT

The Scope-IT application collects, prepares, and approves the turnaround worklist. This application organizes the different work requests and provides information on the scope regarding safety, budget, and environment to analyze and asses the approval or rejection of the work order. This application generates reports to provide insight into the scope and to trace all relevant information attached to the scope. The applications functionality allows; the assignation of scope cost that provides control over the scope budget, import and export of data with ERP systems, clusterization and categorization of scope without loss of detailed information, creation of risk matrix and provision of risk analysis, and export of all collected scope information to System-IT application.

System-IT

The System-IT application is used for the preparation, maintenance, and execution of work packages. With the use of predetermined templates, the application enhances the preparation and estimation of planned activities and allows material assignation to these activities. It also allows collaboration between different users and disciplines, by allowing simultaneous work on the scope items which guarantees integration of information from the different specialist providing details on QAQC requirements set by them. The application also provides a progress overview of scope items, which allows the identification of trends. Systems-IT also contains interface options with scheduling and ERP systems.

4.2.3. TAR2019 Software Interaction and available data

As can be appreciated, the different software exposed provide a wide variety of applications and functions. Some of these applications and functions between suits are related and may overlap on functionality. Because of this, turnaround owners mix and match the different applications from the different providers to adequately address the needs of their organization. When selecting the applications and systems, turnaround owners take into account their organization's everyday software use and licensing, as well as the integration or interoperability between systems. Appendix B is an example of this mixing and matching of the different functionalities used for TAR2019 as it shows the data workflow between the different systems.

It has already been established from the initial POC that the data to be visualized is labor resources which are assigned in Roser’s Systems-IT, Discipline categorization which is also assigned in Roser’s Systems-IT, schedule data which is assigned in Primavera P6, and the geospatial data which is assigned to the element from the ERP system.

Setting focus on the flow of information, it can be appreciated from the diagram that work packages are exported from Roser’s Systems-IT to Primavera P6 through its API. With work packages in Primavera P6, the application adds time component and allows scheduling and planning of the different task that composes the work package. After the planning, and scheduling phase, the base plan of the turnaround activities is set, and data is then exported, again through Primavera's API, back into Roser.

Focusing on the execution phase, which is the focus of the research, figure 5 shows the data flow during the execution phase of the TAR2019. With the schedule baseline set, the turnaround goes into the execution phase with the information in Roser’s System-IT. As activities are executed, progress is inputted through different sources, which then updates the data on the state of the task. At the end of the shift or working day, updated data is exported to Primavera P6 so that delayed tasks or emergent work is rescheduled and then sent back to System-IT.

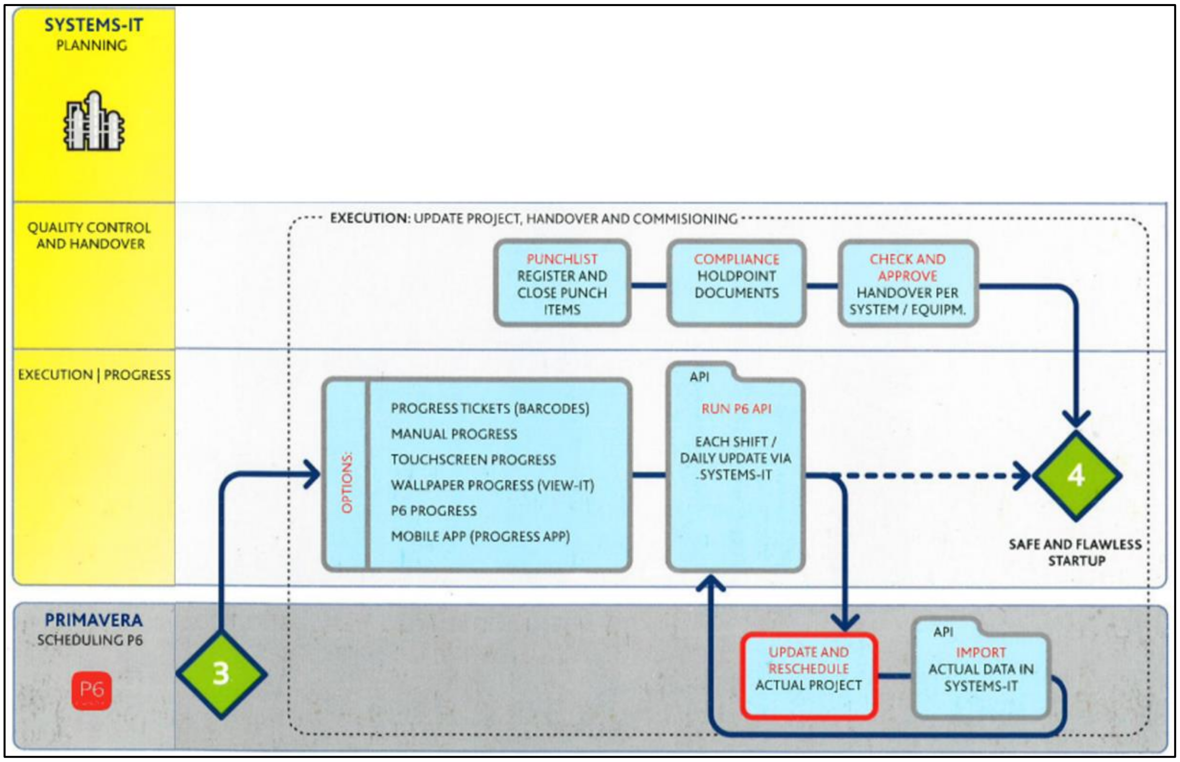

Figure 5 The Data Flow During The Execution Phase Of The TAR2019

This leaves two possible information sources where the data can be extracted. Roser's Systems-IT which works with an SQL database and Primavera P6 which possess interoperable API or can be retrieved through the Oracle Database. If data can be integrated between the source and visualization mean, the selection of the different sources will provide different information. If the visualization tool is linked to Roser's Systems-IT, the visualized data will be continually up to date, assuming that progress is inputted in the correct way and at the right time. On the other hand, if the visualization tool is linked to Primavera P6, the data visualized would be updated with each shift or working day, meaning that progress during the day will not be visualized until data is exported to Primavera for updates and reschedules. This information is relevant when choosing the means for visualization as the software chosen might be, or not, interoperable between the different sources of information. Also, the way information is updated will also have changes in the way data is visualized. These two points will be considered in the following subchapter when deciding on the visualization means in order to assure an ideal flow of information.

4.3. Visualization Means

This subchapter will be dedicated to the selection of the visualization means. Essentially the visualization means refers to the software or application that will be used to deliver the final product. The subchapter is divided into three sections. First, an introduction to GIS. Subsequently, a literature review on the uses of the chosen GIS technology will be presented with the goal of proving that the chosen technology is suitable for the goals of the research. The subchapter will finalize by introducing the software chosen and the motivation for the selection.

4.3.1. GIS

Given the requirements set by the client, three different aspects will drive the selection of the visualization means. First, the visualization means must work in a 3D geographical domain. Second, the visualization means shall include different navigation requirements so the users can interact with the visualized scene. Third, the visualization means should be interoperable with common turnaround information systems or databases to achieve automation in updating visualized data. From these requirements and an analysis of the technologies, available, GIS technologies were discovered.

Geographic information systems (GIS) is a special-purpose digital database in which a spatial coordinate system is the primary means of reference. This means that information sets in GIS are linked to a spatial geo-reference and thus categorizing GIS as "the science of where" (2013, Kennedy, M. D.). It is an integration of computer hardware and software which can create manipulate and analyze a geographically referenced database to produce new maps and tabular data (2014, Martin, D.). GIS provides a platform for understanding trends and behaviors on at all scales locally, regionally, and globally. Presenting a way to comprehend these behaviors and trends of the world as well by simplifying and communicating the analyzed data using the universal language of mapping on a local or global scale. GIS can be used in a wide variety of applications. According to Chrisman's (2002) book, exploring geographic information systems, GIS is used on a general level to:

- Measure aspects of geographic phenomena and processes;
- Represent these measurements, usually in the form of a computer database, to emphasize spatial themes, entities, and relationships;
- Operate upon these representations to produce more measurements and to discover new relationships by integrating disparate sources; and
- Transform these representations to conform to other frameworks of entities and relationships.

All this with the primary goal of generating a visual tool that communicates, perform analyses, shares information, and solves complex problems. GIS technologies allow flexible and interactive visual representations of data and uses a georeferenced database as its source of information. Given the requirements set, GIS seems like a proper tool for regrouping relevant information and visualizing data in a more interpretable and accessible format. To truly fix GIS as the chosen technology to tackle the requirements for the visualization tool, a literature review will be conducted to find if GIS technologies are used in functions similar to those intended by this research.

4.3.2. GIS use in Turnarounds Context

GIS technologies have interdisciplinary applications in distinct fields like geodesy (projects, surveying, cartography), remote sensing, photogrammetry, environmental science, city planning, cognitive science, among others (Prathibha, 2014). A literature review was conducted to grasp if GIS technologies have been used in Turnarounds. No literature was found on the use of GIS technologies specifically on turnarounds. Even though comparing construction projects with turnarounds is unfair, Duffaa and Ben-Daya (2009) argue that in general, the construction project management body of knowledge applies to Turnaround management to a certain extent. For this reason, the literature review looked into the use of GIS in the construction industry.

Bansal (2012) provides a literature study on the applications of GIS in the different phases of the construction industry. Ho and Miles (1999) argue that the added value of GIS technologies in the construction industry is that as they possess the quality of accessing, processing, and communicating both graphical and non-graphical information quickly, there is the potential for improving planning and decision making, and promote better organizational integration and knowledge management. Figure 6 provides an overview of the different applications adapted from Bansal's (2012) study.

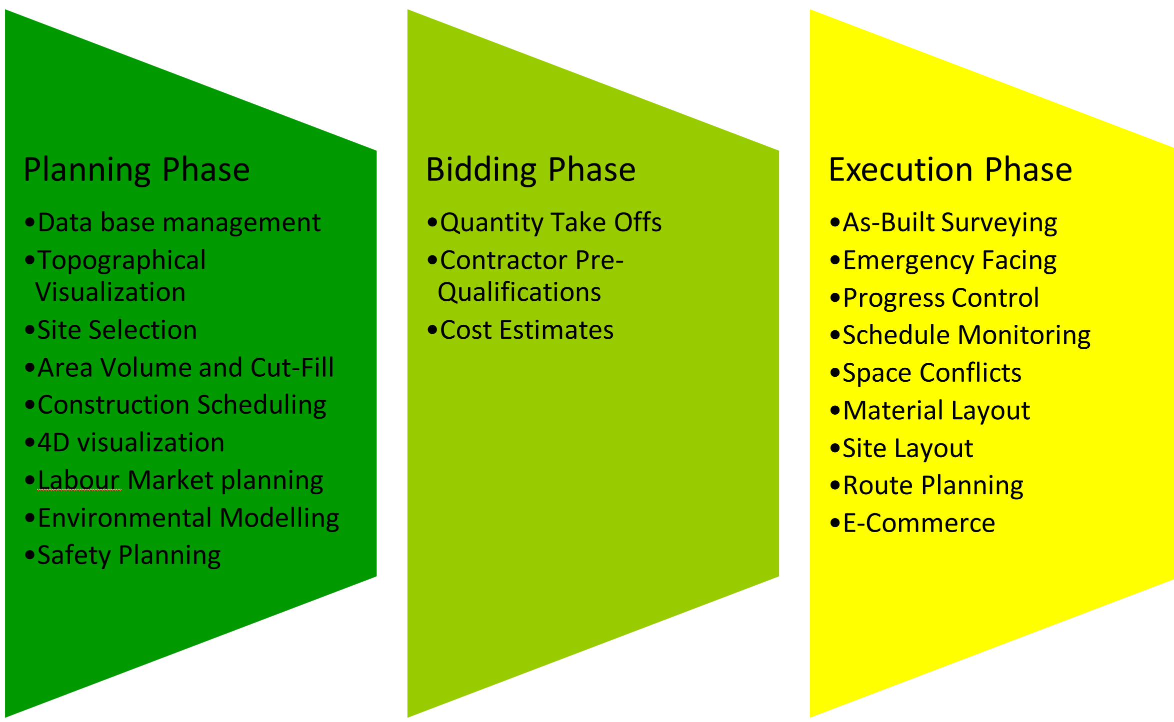

Figure 6 GIS Applications On Project Management

From figure 6 the literature review will focus on the project management application of GIS technology that is relevant and comparable to turnaround management. Jeljeli (1993) argues that even though GIS technologies are widely used for their technical analysis capabilities, GIS technologies can also provide organizational analysis on the sociological and economic feasibility of different decisions made during the planning phase of the project. Sun and Hasell (2002) agree with these arguments as they conclude that the GIS's Spatial database integrated with project management functions provide a powerful management control system.

Several pieces of research were found on the use of GIS for visual scheduling of construction projects during the planning phase. Cheng and Yang (2001) argue that because planners make decisions on a wide variety of information, GIS provides a useful integration of location and thematic information into one sizeable georeferenced database, which makes the planning process less tedious. Most of the literature found on the visualization of schedules overlap with the uses of BIM's 4D simulations. For example, Zhong et al. (2004) developed a GIS-based visual simulation system which takes construction elements in a 3D environment and simulates them over time with the construction sequence. Schouten (2015) evaluated the implementation of 2D GIS visualization model for planning maintenance work of railway tracks.

Poku and Arditi (2006) in their research argue that the added value of the use of GIS technologies in visually monitoring construction schedules is not necessarily the visualization aspect that may already be provided by 4D BIM simulations. It is instead the use of databases and connectivity to other project management software's that allows integration of information and therefore automation in updating the data visualized, which provides real-time and complete information to the different stakeholders. Cheng and Chen (2002) also developed an automated scheduling monitoring system to control the transportation and erection of precast buildings. Using a barcode system and wireless radio technology to collect and transmit relevant data. The system then allows automated update of the progress of precast transport and erection; this way, stakeholders off-site can monitor on a real-time basis the construction progress through integrated and consistent data.

Dib, Adamo-ViIIani, and Issa's (2013) research argues that GIS technologies provide a "one place to go" to retrieve the information needed to either design, plan, or execute an activity. This is thanks to GIS's interoperability with, ERP systems, DBMS, and even common project management scheduling tools like Primavera P6. They also argue that GIS technologies have automatic updating possibilities which allow the different team members, both on-site and in the office, to have access to the latest up to date information. This generates benefits for the communication and coordination between project stakeholders. These are the reduction of loss of information, the reduction of cost overruns caused by miscommunication and scope changes, the reduction of time loss as less effort is spent on communicating and tracking changes, and the reduction of time lost due to the increased extent to which information cascades and is interpreted through different project members (Dib et al. 2013).

Researches were also found on-site design and site utilization. Hegazy (2005) generated an attractive maintenance-portfolio schedule optimization model using GIS technologies for distributed site locations. His model used site-specific information to calculate distances to optimize schedules using the shortest travel times while considering the construction method, resource, time, and cost constraints. Also, on-site layout, Cheng and O'Connor (1996), argue that temporal construction facility layout design usually involves using sketches and 2D drawings, which makes the thought process highly experienced based. They developed a GIS-based model to integrate relevant layout information like surrounding facilities and project 3D model to perform a series of spatial operations to select ideal temporal construction facility layout to reduce travel time and possible spatial clashes. Cheng and Yang (2001) and Su et al. (2012) developed GIS-based models to optimize material layout by considering material quantities, transportation method within site, distances, project schedule, size of materials, and designated storage areas. With their models, they assist the project on an ideal material layout to prevent congestions or inaccessibility to required materials.

As GIS technologies provide multidimensional workspaces, they can perform spatial conflict analysis similar to BIM's clash detection. However, rather than focusing on the integrity of the design of the building in BIM's clash detection, GIS technologies provide a broader spectrum of spatial analysis that can enhance organizational factors. Bansal (2011) argues that GIS technologies can generate multiple types of spaces not necessarily restricted by physical elements. This means that GIS can simulate working areas or space consumed by different activities by assigning relevant working space information to the location and time of the activity. Not only can these activities be simulated, but analysis can also be made on clashes between activity to activity, activity to physical object, and physical object to physical object over the project duration. Bansal's (2012) conclusions on future uses of GIS technologies for the construction industry is very much in line with the knowledge gap found in this as he states that:

"The author also feels the need for operational level visualization in GIS to explore construction plans for better and effective planning fully. It provides keys to significant savings in project time, costs, and reduction of several unwanted problems…Viewing the interaction among different crews and/or equipment must be part of the operational level visualization, which is an important factor in meeting the project schedule. Therefore, we need to have more research on construction operation simulation in GIS." (P.29)

From the exposed literature review on the uses of GIS technologies as project management tools for the construction industry there are essential aspects relevant to this research to point out;

- GIS technologies can be used and have been demonstrated to work as project management tools, especially for visual representations of the schedules, which is relatable with this research.
- GIS technology's benefit from information integrity and interoperability, which can enhance organization, coordination, and communication.
- GIS technologies can provide operational level visualization, making the integration between schedule, labor, and geospatial data possible.

From these aspects, it can be concluded that there is sufficient background information motivating the use of GIS technologies to tackle the requirements for the visualization of labor resources set by the client. The next section will introduce the specific GIS software that will be used to develop the visualization tool.

4.3.3. Selection of Software

There is a wide variety of GIS software in the market, varying in functionality and applications. Some software work only in 2D, while others have 3D capabilities. As appreciated in section 3.1.1 on the description of the client, the oil industry is divided into upstream and downstream sectors. Even though BPRR belongs to the downstream sector, all BP subsidiaries have a general organizational software licensing program. After selecting GIS technology as suitable for the visualization tool, it was found that the client organization had licensing for ESRI software, which is used in the upstream sector of BP plc for basin and topographic analysis. Environmental Systems Research Institute (ESRI) is the market-leading developer of GIS technologies. Their main product is the ArcGIS Suite which mainly consists of;

- ArcCatalog which is the data management application used to browse datasets and files,
- ArcGIS Online which is the web-based app for geographic information scene sharing,
- ArcMap, which is the 2D GIS desktop software,

- And, ArcGIS PRO which is a GIS desktop software which was introduced in 2015 and was considered as the new generation of GIS software as it possesses 3D GIS capabilities.

After a study on the different ESRI products comparing their functionalities with the requirements of the visualization tool, it was clear that the ArcGIS PRO software fits most of the requirements of the visualization tool. Initially evident as it is the only ESRI software that works within a 3D domain, meaning that it will include the functional specification on navigating in a 3D environment. However, the most crucial aspect that makes ArcGIS PRO ideal, specifically for this research, is that the software can be directly connected to different DBMS and ERPs like Microsoft SQL databases or Oracle Databases. This is ideal because, as exposed in subchapter 4.2, the ROSER suite is a DBMS that uses a Microsoft SQL Server database, and Primavera P6 works with an Oracle server database. ArcGIS PRO can then retrieve information from both sources assuring information integrity and evidencing the interoperability benefits of GIS technologies as previously described in is chapter. Figure 7 shows the possible data flow diagrams that can feed data to ArcGIS PRO. This diagram originates from the original state of the data flow diagram for the TAR2019 shown in section 4.2.4.

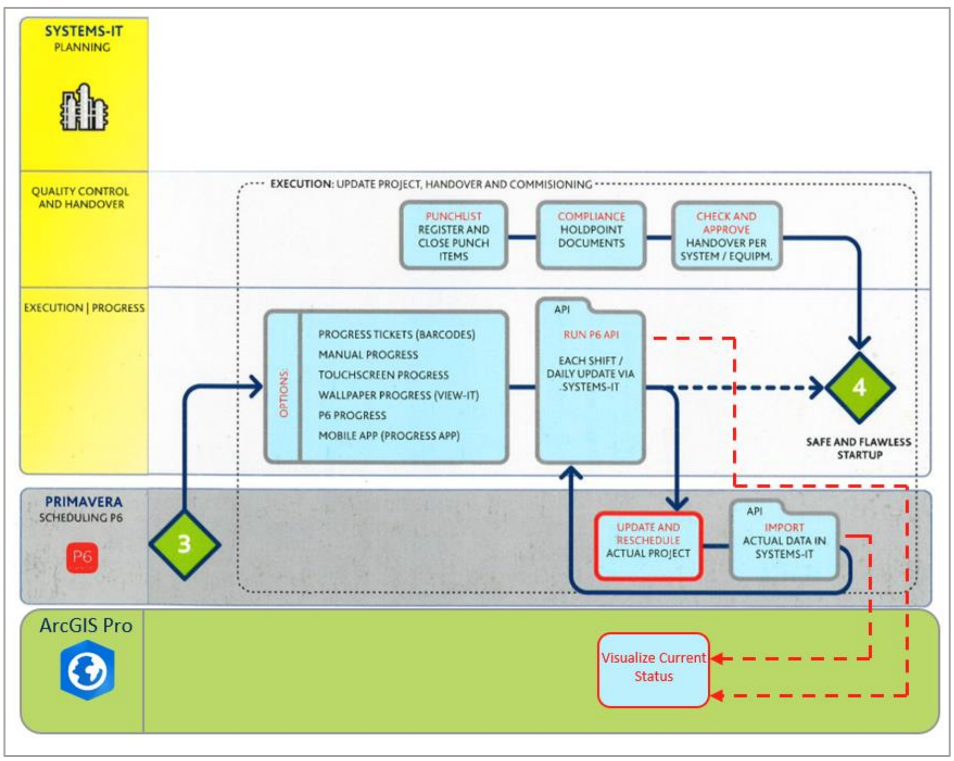

Figure 7 TAR2019 Data Flow Diagram with ArcGIS Pro

4.4. Conceptual Design

Now that the visualization software has been chosen this subchapter will be dedicated to setting the conceptual design of the visualization tool. First, a section will be dedicated to the space-time cube concept. After which, a section will be dedicated on the final modified Space-Labor Cube with temporal animation, which will set the initial concept for the preliminary design.

4.4.1. Space-Time Cube

Digging into the toolbox integrated within ArcGIS PRO. A toolbox category was found on Space-Time Pattern Mining, which statistically analyses data distributions and patterns considering spatial and temporal features. The toolbox contains two related tools, Create Space-Time Cube and Emerging Hot spot analysis.

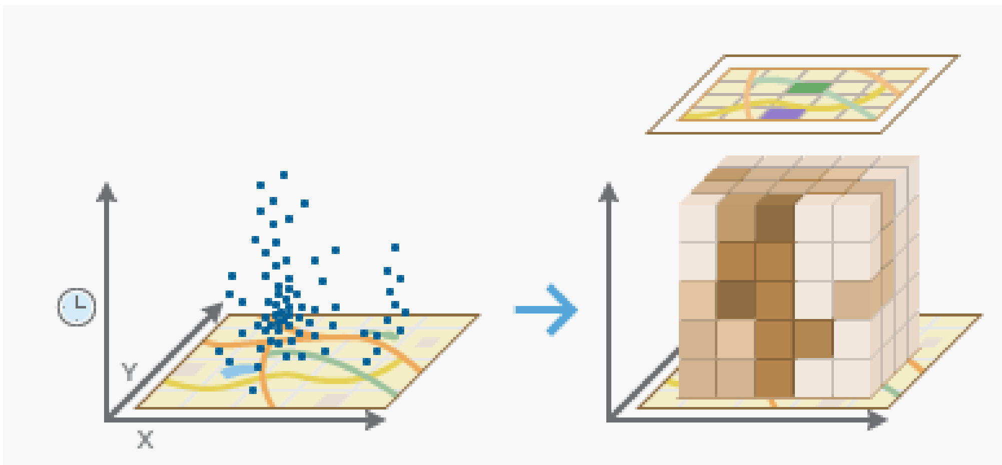

Figure 8 The Aggregation Of Point Datasets Into Space-Time Bins (ESRI, 2019)

The Create Space-Time Cube tool creates a multidimensional data visualization cube structure based on the aggregation of point datasets into space-time bins as appreciated in figure 8 taken from ESRI's (2019) online training academy. The input information of the tool is a point dataset where each point represents an activity, with x, y coordinate reference, and a temporal reference in the z coordinate. The tool then counts how many individual points or activities fall within a selected time step interval and specific distance interval, which is represented by a bin. The information provided by the space-time cube is a 3D hotspot analysis where the colors of the bins will change depending on the count of individual points within the bin. Figure 9 shows the conceptual design of a space-time cube found in ESRI's (2019) online tool reference.

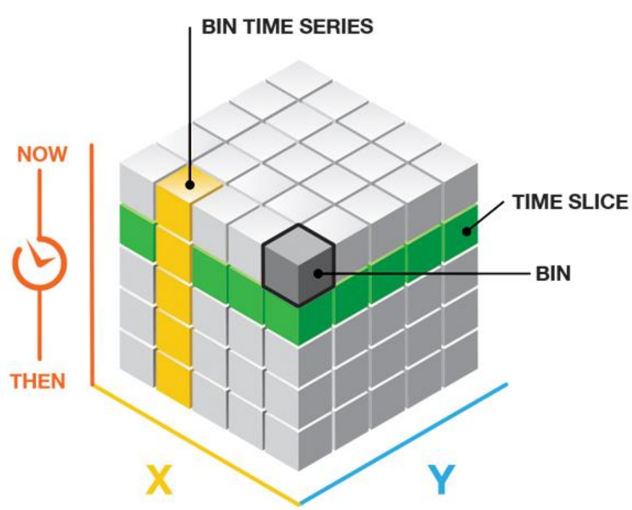

Figure 9 space-time cube (ESRI, 2019)

Given the established coordinate system (X, Y, T) and the functionality of the tool, it is evident that the cube will display hot spots over time where time is the Z coordinate. This means that all bins will be the same size in both area (X, Y Coordinate) and height (time interval) and the differentiation between bins, besides the assigned coordinate and time interval, would be the color that categorizes the hotspots which are defined by the number of points from the source data that fall within the bin volume. The columns that are composed of several bins represent a time series for the specific assigned coordinate. The transversal cut of the cube will represent a time slice which shows all bins on the X and Y coordinate for the specific time range.

Even though the space-time cube represents the distribution or accumulation of activities, it does not fit the requirements for the visualization tool. The intended visualization tool, rather than accumulating the number of activities that fall within the time step interval, must accumulate the amount of labor resources assigned to that activity while differentiating on the discipline category and coordinate specific activity has assigned. Because of the way data is aggregated and displayed the space-time cube tool will not cover the requirements for the tool. No single ArcGIS tool seems to cover the requirements set. However, the concept can be adopted and modified to meet the visualization tool's requirements by integrating different toolsets.

4.4.2. Modified Space-Labor Cube plus Time

Looking at figure 9 on the space-time cube concept adopted from ESRI (2019), and recalling the coordinate system made in the subchapter 4.1 as represented in figure 10. The original space-time cube works in 3D graphical space, while the intended visualization tool also works in 3D graphical space but the Z-axis represents the accumulation of labor resources, and also a 4th dimension must be included which is the time element, which will be represented by a time step interval animation.

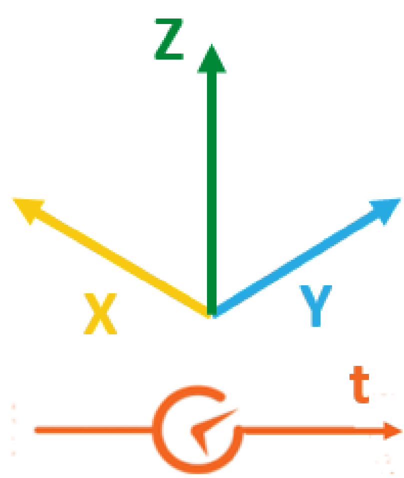

Figure 10 Intended Dimensions

The final conceptual design for the visualization tool will then be a modified Space-Labor Cube with temporal animation. Where a single Bin will represent the accumulated labor resources for a specific day or shift and a specific discipline category which will be represented by different colors. The column will now represent the accumulated labor resources that must be spent in that specific coordinate area for the desired time interval. In the column, differentiation will be made on the colors that compose the column, which will categorize the different disciplines that compose the scope for that area. The input information will then be activities represented by points where not only do they have an x and y coordinate, but they also contain relevant information about the task like labor resources, planned start and planned finish which will satisfy the initial requirements for the visualization tool. Because the space-time cube tool did not fit the initial requirements for the tool, the construction of the final conceptual model will have to be made using a set of different tools which will be described in the following chapter. The final conceptual model of the modified Space-Labor Cube with temporal animation is presented in figure 11.

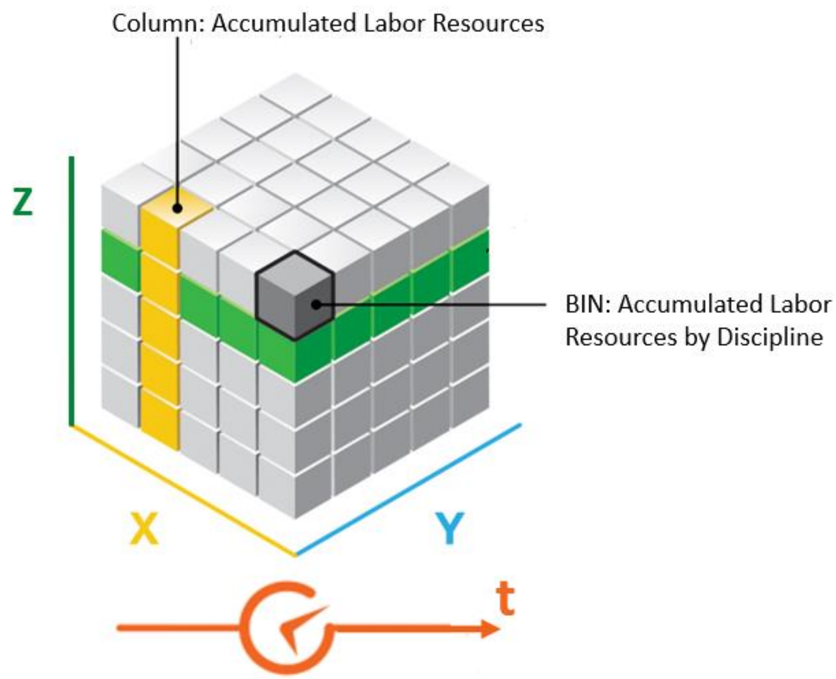

Figure 11 Modified Space-Labor Cube with Temporal Animation

5. Preliminary Design

The third stage of the Dym and Little cycle focus on the actual development of the conceptual design into a preliminary design. In this stage, the established conceptual design will be developed through the visualization mean chosen. The stage describes, on a technical level, how conceptual design is refined and optimized to meet the performance and operating requirements. This chapter follows a logical sequence. First tests will be conducted to understand the capabilities of ArcGIS PRO and to check whether the software allows or has specific restrictions for the desired visualization. These tests will be using random data that is queried and organized outside ArcGIS PRO to fit the characteristics of the test conducted. Once all initial requirements have been tested, a section will be dedicated to the description of the data received from the database and its implication. Once the data is made clear, this chapter will focus on the actual queries and operations within ArcGIS PRO with real project data. The end product of this chapter is a detailed description of the operations and queries used to visualize the desired data. The goal of this chapter is to develop the conceptual design as much as possible to fit the initial proof of concept into the visualization mean.

5.1.Refinery Grid and Coordinate System

The Refinery plot uses a grid system to assign a location to the different components that conform the refinery as appreciated in Appendix C for Area-1 and Appendix D for Area-2 and 3. This grid is a 10m x 10m system that takes as origin the crossroad of electrical substation A. This origin represented in the grid coordinates (OI,163) and with rijksdriehoekstelsel coordinates of (66797.1032, 439922.0690) is used to create a simplified coordinate system for the refinery. This simplified coordinate system will be referred to as the BPRR coordinate system. The origin was assigned in the BPRR coordinate system as coordinates (6485,5265) and assumed the direction of the road in the OI grid line as north for the BPRR coordinate system. This means that when using the coordinate system in ArcGIS Pro either a new coordinate system must be created to fit the BPRR coordinate system, or a function must be created to convert the grid coordinates into rijksdriehoekstelsel coordinates. This must be taken into account because otherwise when point datasets are displayed in ArcGIS Pro, the system must know which coordinate reference to use otherwise the points will not be in line with the actual geographic position.

The researcher reviewed both options and opted for the function to convert the Grid system coordinates. This was done by taking the origin rijksdriehoekstelsel coordinates of (66797.1032, 439922.0690) and calculating the azimuth of the Refinery North which was -12°57'. With this information, it was possible to create a conversion table by calculating the rise in the North and the run in the East for each grid. Figure 12 represents the coordinate conversion layout.

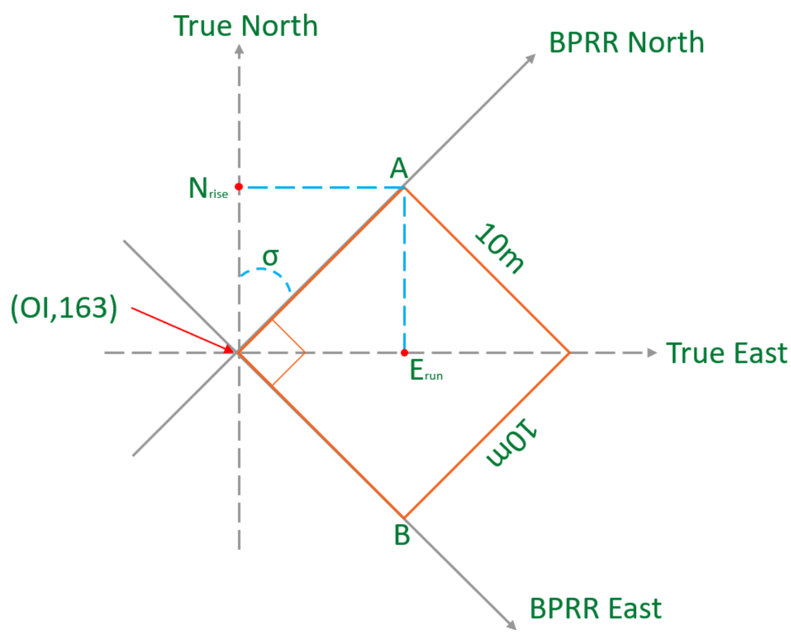

Figure 12 Coordinate Conversion Layout.

$$E_{run} = sen(\sigma) * 10 = sen(12°57') * 10 = 2.241007m$$

$$N_{rise} = cos(\sigma) * 10 = sen(12°57') * 10 = 9.745660m$$

With the coordinate conversion set, a table representing the complete grid conversion as presented in Appendix E. The coordinate conversion system was then tested in the ArcGIS PRO to see if the conversion was done correctly. Figure 13 shows the result of this conversion, and as can be appreciated, each point represents the center for the specific 10m x 10m squares that make up the grid.

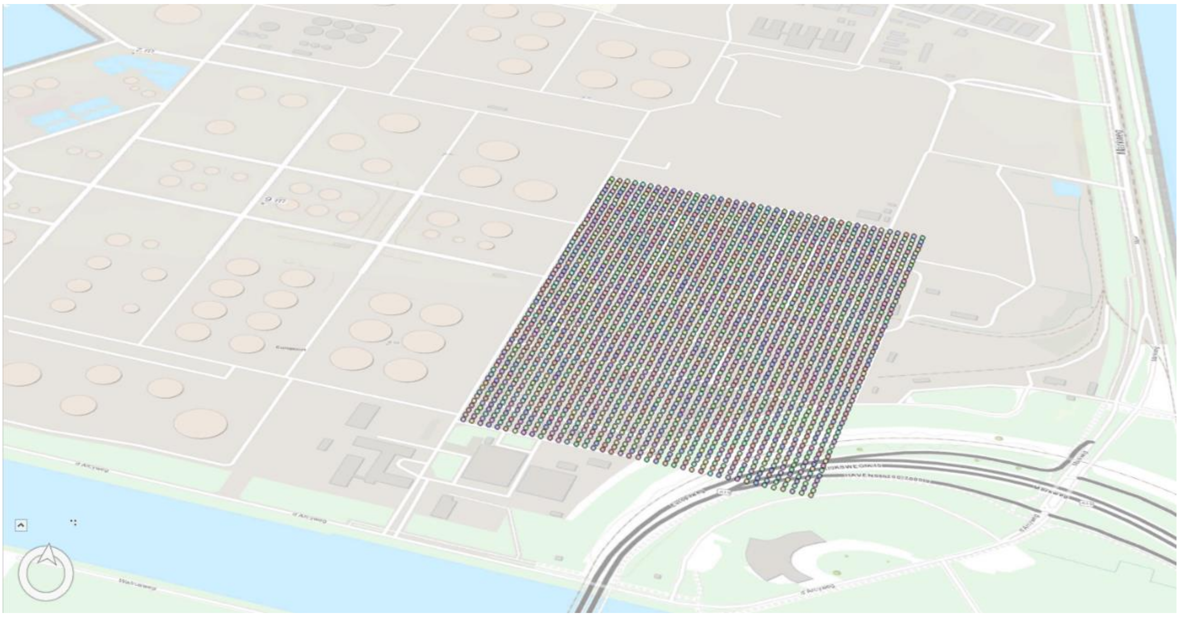

Figure 13 Representation Of Successful Coordinate Conversion

5.2. Z-Axis and Stacking Test

To test the Z-axis, two sets of random numbers were assigned to each coordinate point. Two sets were chosen to test the stacking of data and the representation of labor resources. This means that when the data set is transferred to ArcGIS PRO, two points will be plotted for each grid. The first set taking an offset value of 0 and a height value of the assigned random data set 1, the second set takes the height value of the assigned random data 1 for the same points in the same grid as offset value and a height value of the assigned random data set 2. Figure 14 shows the inputs for the XY table to point geoprocessing tool in ArcGIS PRO, which plots the different dataset.

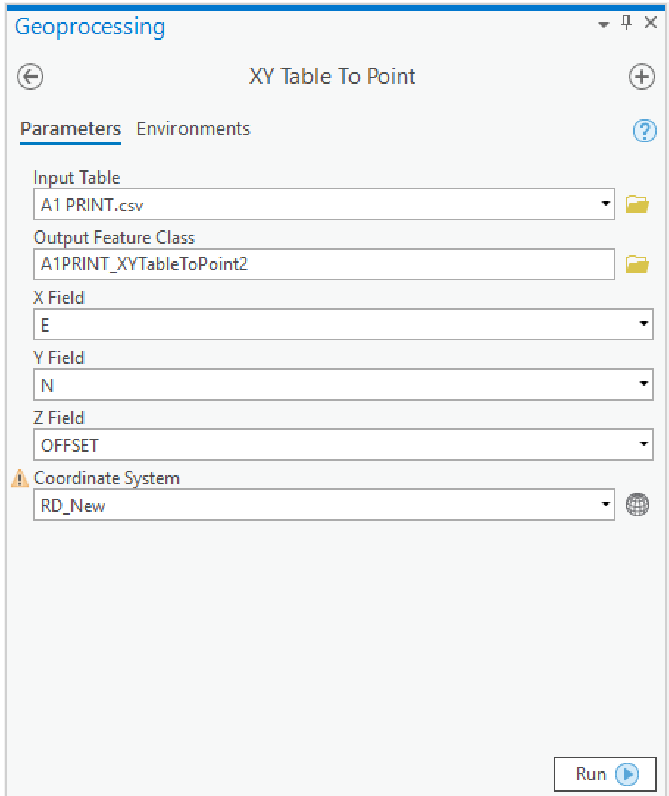

Figure 14 Inputs For The XY Table To Point Geoprocessing Tool In ArcGIS PRO

As appreciated from the figure 14 the input data is X-field which contains the East Coordinates, the Y-field which contains the North Coordinates, the Z field which contains the offset value, and the Coordinate system which as explained in the last section is the rijksdriehoekstelsel coordinate system or according to ArcGIS PRO the RD_New Coordinate system. At this moment, ArcGIS PRO is still displaying the point data sets with an offset value. To give each point the height value, the symbology of the point was changed to a standing cube in which the height value was assigned to the random data sets 1 and 2. The width was set to 4m so that the standing cube fits in the 10m x 10m grid. Red and blue colors were assigned to the different sets of data in order to check that the stacking is done correctly. Figure 15 shows the result of this Z-axis and stacking test.

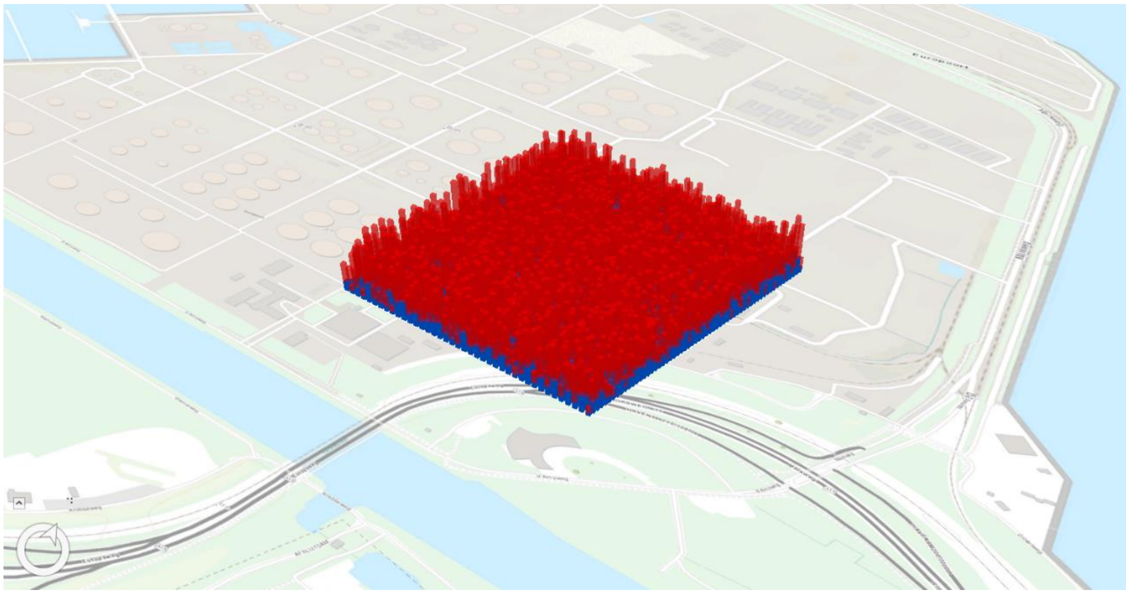

Figure 15 Z-Axis and Stacking Test

5.3.Discipline Categorization Test

As the requirements set by the client indicate the need to differentiate between the different discipline categories that are present in the turnaround. The initial categorization included nine disciplines, which are Mechanical, Cat/Cleaning, Piping, Elect/Instr, Rotating, Inspection, Scaffolding, Support, and Pre/Outside. For the designation of color codes that will represent each category, Trubetskoy (2017) research on distinct color were used to assure that the users distinctly perceive the difference in colors. Appendix F shows the color code diagram adopted from Trubetskoy (2017) research. Now that the color distinction is made for each discipline, the visualization was tested again by assigning random data for each discipline with an aggregation made of the offset so that each discipline is stacked over each other. This means that there were nine different points plotted for each grid, where each point had a specific discipline, grid, height, and offset data. The result of this test is appreciated in figure 16, where there is a clear distinction between the stacked disciplines.

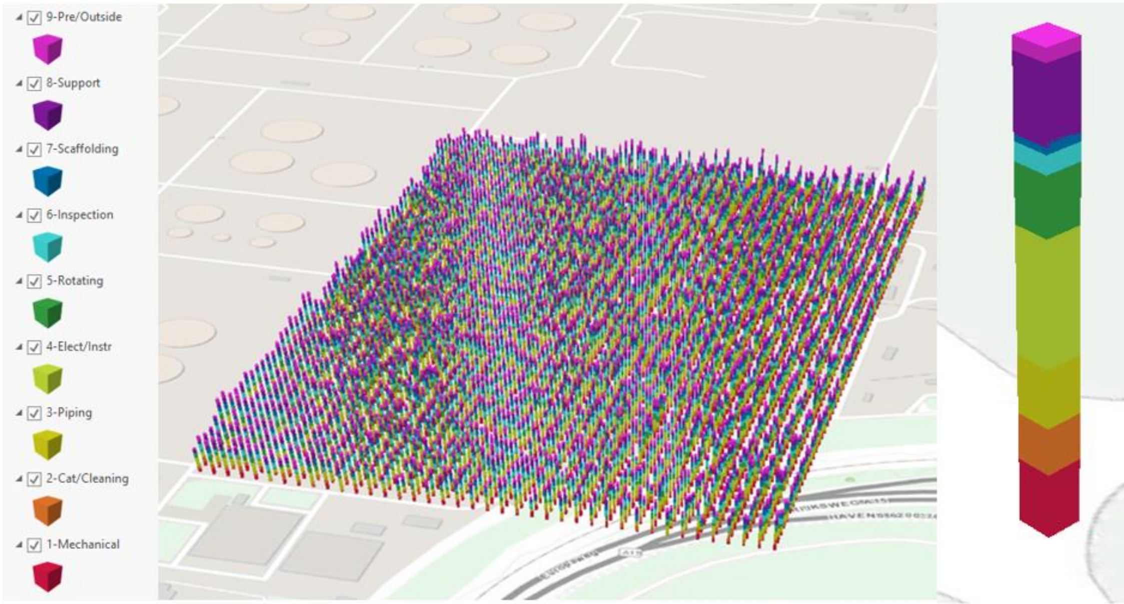

Figure 16 Result of Discipline Categorization Test

5.4.Area Filtering Test

As explained in the case description, the turnaround is divided into three areas. Each of these three areas has a different manager, supervisors, and even contractors. This then requires the tool to be able to filter the different scopes of the area. To test the filtering of areas the data set used for discipline categorization was used were depending on the grid coordinates the area the grid belongs to was assigned. This means that now each data point has X-Y coordinates, offset, height, discipline, and area values. The filtering of the areas could be done in two ways, either using a range tool or by plotting the data in different layers. A decision was made to use different separate layers for each area plot, this way the range tool which can only be used on one attribute can be defined by the user depending on the visualized information he desires to filter out. The result from this test is presented in figures 17, 18, 19, and 20 showing the total area, area-1, area-2, and area-3, respectively.

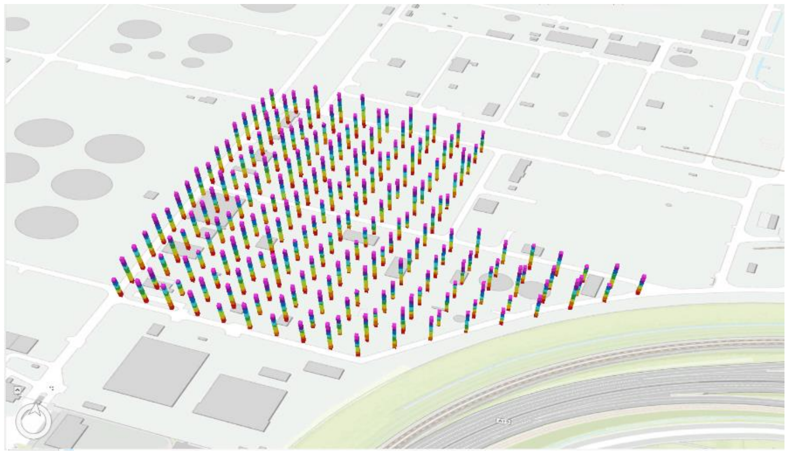

Figure 17 Area Filtering Test Total Area

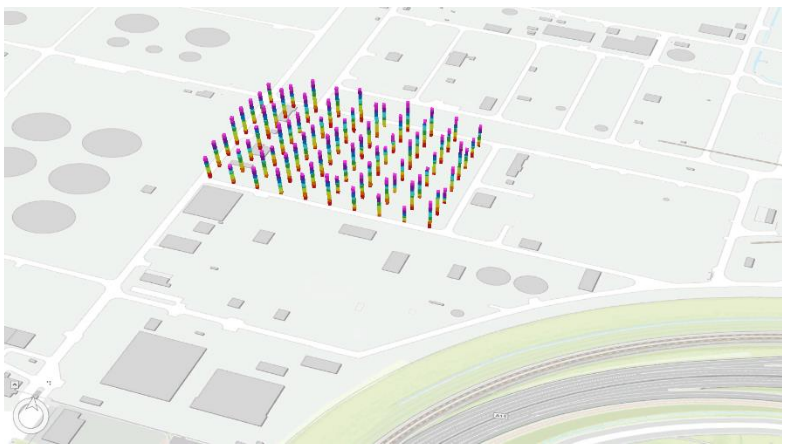

Figure 18 Area Filtering Test Area-1

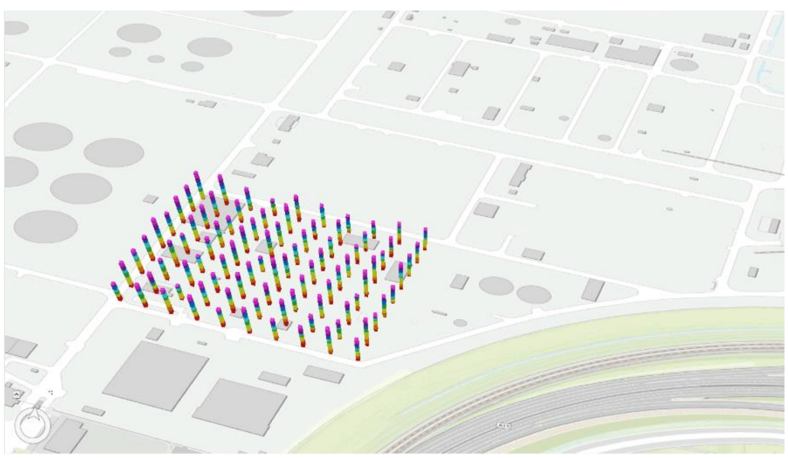

Figure 19 Area Filtering Test Area-2

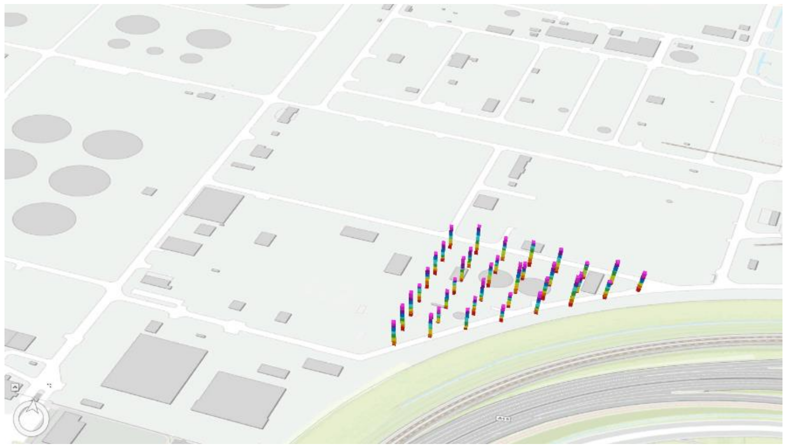

Figure 20 Area Filtering Test Area-3

5.5.Time Testing

For the time testing, time data was assigned to each of the points. ArcGIS PRO has two options when assigning temporal data, an option where each feature has a single time field meaning that the feature exists at a certain point in time and an option where each feature has a start and end time field meaning that the feature exists for a specific duration of time. This is quite relevant for the visualization tool because as the data received are tasks, each feature will have a planned start and planned finish. This then means that the feature will have a duration calculated by subtracting planned start from planned finish. As the goal of this subchapter is to test time, a single date was assigned to each feature, meaning that they only exist in a specific instant. This will not be the case when using real turnaround data. The decision on how data will be visualized will be taken based on the preference of the user, which will be set in the following chapter.

As exposed in the conceptual design, the temporal attribute will be represented as a time step animation. ArcGIS PRO has an integrated time slider control, as shown in figure 21 taken from ESRI's (2019) online tool reference system. With the time slider, users can choose a visible time interval extent and can drag the slider bar or use the back and forward commands to navigate through time.

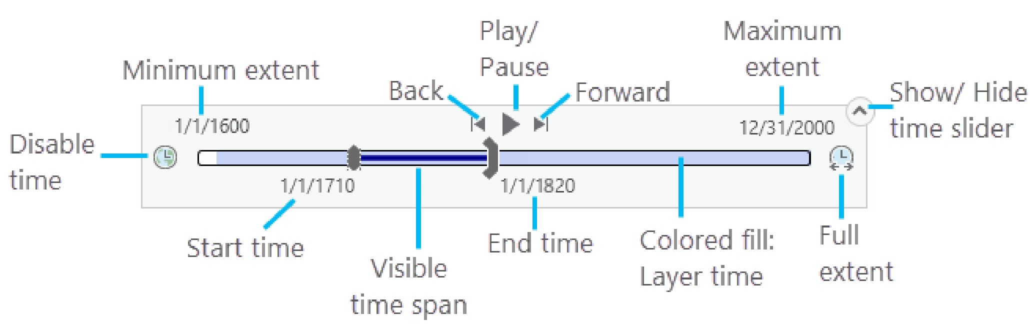

Figure 21 ArcGIS Pro Time Slider Reference

5.6.Integrated-Turnaround Data Description

At this point, all the requirements set have been tested, proving that ArcGIS PRO does have the tools and attributes required to achieve the desired visualization. However, until now, all of the data has been queried and organized externally to ArcGIS PRO, which means that data sets were fixed externally to the software with the sole purpose of testing the different requirements. In the case where real turnaround data will be used, the connection between ArcGIS PRO and the database will allow the data to be fixed within the software. All functions and applications used in the software can be translated into python for automation. Before digging into the data querying within ArcGIS PRO, it is relevant to describe the data received.

As has been described previously, the grid Coordinates are assigned to the different elements that compose the unit in the ERP system. Because the grid system is composed of 10m x 10m grid, the granularity or detail level of the visualization will be driven by this aspect. Because of the fixed granularity, some elements will be intersected by more than one grid. Therefore, the decision on to which grid the element belongs to was decided by the TAR planner and were based on his experience; he assigns the conflicting element to one of the two grids in question. Figure 22 and figure 23 show an example of a conflicting element where the table shows the data with the assigned grid coordinates as found in the ERP system, and the figure 23 shows the plot of the conflicting element.

SCOPENR	FUNCTIONALLOCATION	SHORTCODE	OBS	WPHOLDER	AreaCode	Building	Elevation
2018031	1001-0600-02-02-D602	DR - DRUM	1.2 - AREA-2	mdegoeij	PF - PF	158 - 158	0

Figure 22 Example Data With The Assigned Grid Coordinates As Found In The ERP System

Figure 23 Plot Of The Conflicting Element

Another essential aspect to point out are the tasks that involve piping work. As the refinery is connected through pipes, it is not possible to assign a grid coordinate to the actual element as the pipe will cover a large extent. For this reason, the assignation of the grid coordinated for piping work was not dependent on the element. The planner also assigned the grid coordinates for piping work but based on the location of the tasks, rather than the element location. This data on the location of the task for piping works is inputted in the Roser suite.

Regarding the temporal information received from the database, there are three different schedule dates. The base plan is the planned schedule before the start of the execution phase of the project and will not change over time as this temporal data serves as a benchmarking tool to evaluate the original base plan with what actually happened during the execution phase. The base plan will be referred to as the base plan start (BPS), and the base plan finish (BPF). The actual schedule, which shows the actual execution date of the task, meaning that at the start of the turnaround data from the actual schedule will be null as nothing has been executed yet. The actual schedule will be referred to as the actual start (AS) and actual finish (AF), this data can be used to check progress and to compare at the end of the turnaround with the planned start. The third temporal data set is the planned schedule based on a three day look ahead this means that the schedule will continuously change on a day to day basis as it depends on the progress made and on extra emerging scope, were delayed activities and extra work-related activities will be rescheduled. The planned schedule based on the three-day look ahead will be referred to as planned start (PS) and planed finished (PF). For the visualization tool, the relevant temporal data is the planned schedule based on the three-day lookahead. This is because this schedule is the one that is providing the information to the stakeholders on what has to be executed based on an updated schedule.

Appendix G shows a table representing an example of the data relevant to the visualization for this research. The different information presented will be described in figure 24.

Data Type	Description
Scope No.	The assigned scope number of the task
Job	Job Code and Description
Scopecode	Scopecode differentiated between maintenance, projects and microproject scope (Integrated Turnarounds)
EWR	Extra work request, describes whether the task was planned or caused by extra emerging scope.
Resources	Subcategorization of the different disciplines
Contractor	The contractor assigned to the task
Total Hour	Labor resources
BPS	Base Plan Start
BPF	Base Plan Finish
PS	Planned Start
PF	Planned Finish
AS	Actual Start
AF	Actual Finish
Progress	Value from 0 to 1 representing the percentage of the task completed
WBS	The area where the task must be executed
OBS	The Supervisor-Assigned to the task
GRID ALPH	Horizontal grid coordinate (Letters)
GRID NUM	Vertical grid coordinated (Numbers)
Discipline	The discipline that the task entails

Figure 24 Table With Data Description

From the table presented in Appendix G, the evidence of integrated turnarounds is evident as the data set includes scopecode data. As BPRR does not differentiate between project and maintenance scope of the turnaround in scheduling, it is this scopecode that informs the stakeholder what type of scope the task belongs too. The possible options defer in the scope of the integrated turnaround but also on whether it is additional scope or emergent from extra work requests. The possible categorizations of the scope are; BSC - Basic Tar Scope Maintenance, Portfolio - Project Portfolio, MICRO - Project Micro, EWR - Extra Work Maintenance, MICRO EWR - EWR Scope Project Port-Folio, PORT EWR - EWR Scope Project Port-Folio, ADD - Additional Scope Maintenance, and End of Life.

Another vital aspect to take into account is the progress data. This value will range from 0 - 1 and will describe the progress of the task. This progress, as can be seen in the information flow diagram in section 4.2.4 on software interaction, can be input by different means and different stakeholders. When visualizing the activities, it has been agreed that all tasks with a value of 1, meaning that they are complete, will no longer be visualized. This is done so that the stakeholder visualizes only the relevant data during the execution phase, which are the tasks yet to be completed. Also, it is essential to point out that the data visualized will consider the data as received from the database meaning that if tasks are delayed and have not been rescheduled or if progress has not been reported the task will continue to appear in the date according to the planned schedule. Because of this, some tasks will appear in the past. Now that the data received from the database has been introduced the queries made within ArcGIS PRO software will be explained.

5.7.Polygon Query Grid

In order to query the input data by the defined granularity of the BPRR’s grid system, a polygon grid system must be created. This polygon grid system will mimic BPRR’s grid system and will serve as an intersection element to query the input data. In order to create the polygon grid system, the ArcGIS geoprocessing tool create fishnet will be used. The fishnet tool creates a grid which is stored as multiple polygon features. Fishnet tool requires the input of origin coordinate, which in this case is (OI, 163) and the direction of the grid, which would be set by the point (OI,90). By specifying the grid width and height of 10m x 10m and the number of rows and columns which is 74 and 62 respectively, the fishnet toolbox generates a 10m x 10m polygon grid system covering the complete area of the Turnaround. Figure 25 shows the data inputted into the tool, and figure 26 shows the resulting polygon grid system.

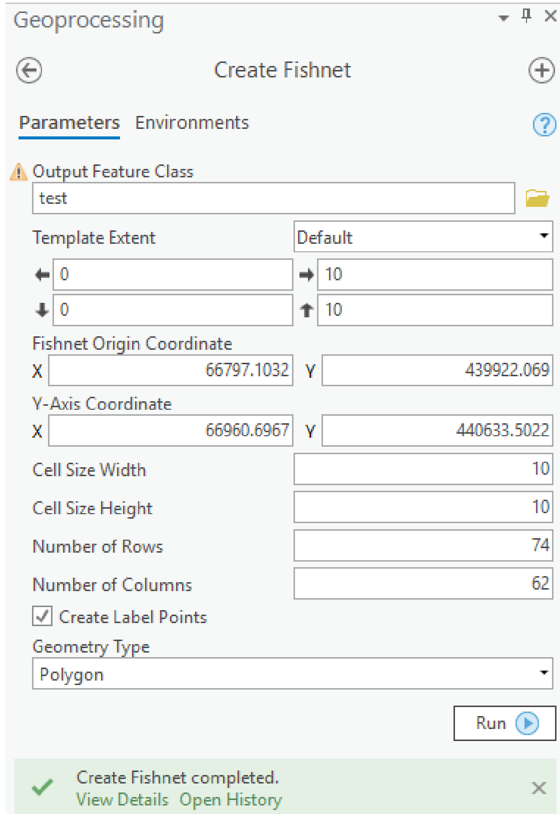

Figure 25 Inputs For Fishnet Tool

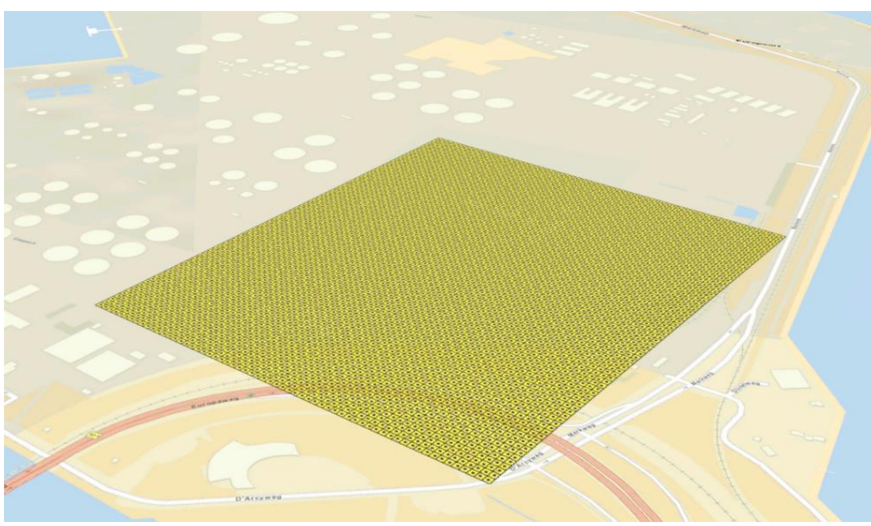

Figure 26 Resulting Polygon Grid System

5.8.Plot XY Data

Now that the polygon grid system is set the tasks can be plotted in the scene using the Display XY Data tool, the task will be plotted as points in their respective grid. As stated, before the data, will be plotted by layers differentiating the different areas. The resulting scene is the combination between the grid system and the plotted tasks as appreciated in figure 27. The colors of the points represent the different area scopes. Even though it cannot be appreciated in the figure 27, many points are overlapping within each grid as there are many activities within the same area.

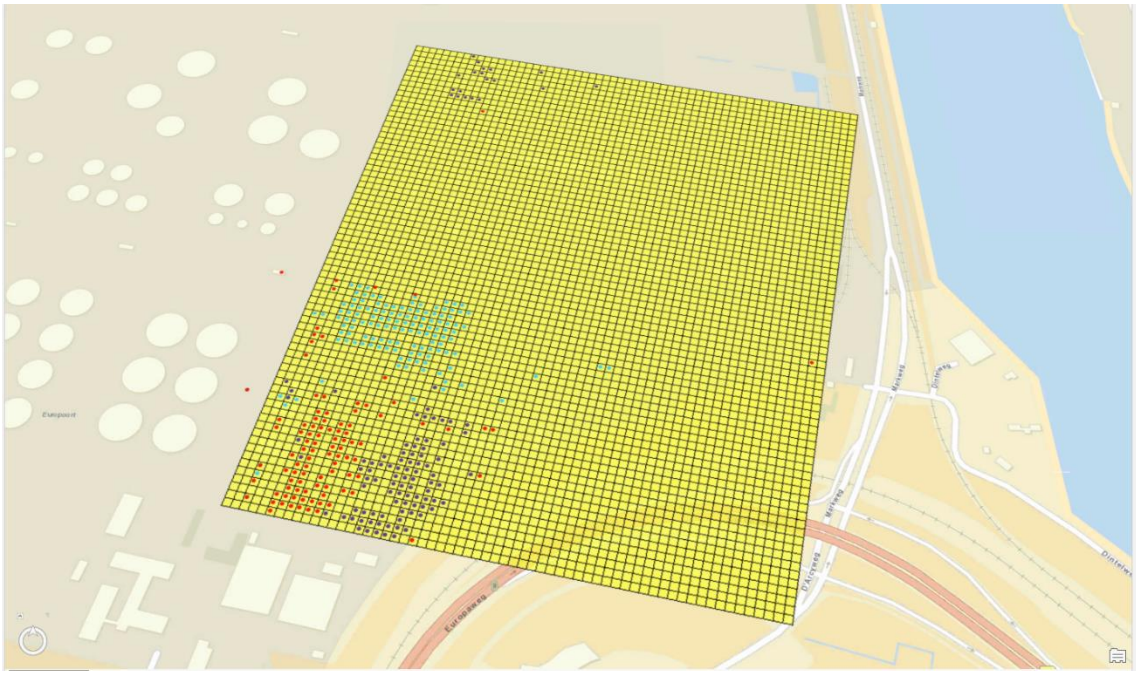

Figure 27 Combination Between The Grid System And The Plotted Tasks

5.9. Query Data by Discipline Aggregation

The tasks represented as points were dissolved using the ArcGIS PRO dissolve tool. This tool aggregate features based on specifically selected attributes. The attributes selected to dissolve were the discipline, grid system, date, and Scope Area, while the aggregate feature was the total hours representing the labor resources. With this query, the tasks were dissolved by discipline while aggregating the labor resources; this means that all tasks with the same discipline and the same grid were added together in the total hour's feature. The result from this query is that now each grid has a maximum of 9 points one for each discipline instead of one point representing each individual task. This does not mean that information is lost. ArcGIS allows multipoint systems, which implies that the feature which represents more than one physical element is only referencing some of the attributes within the conglomerate of point in the database.

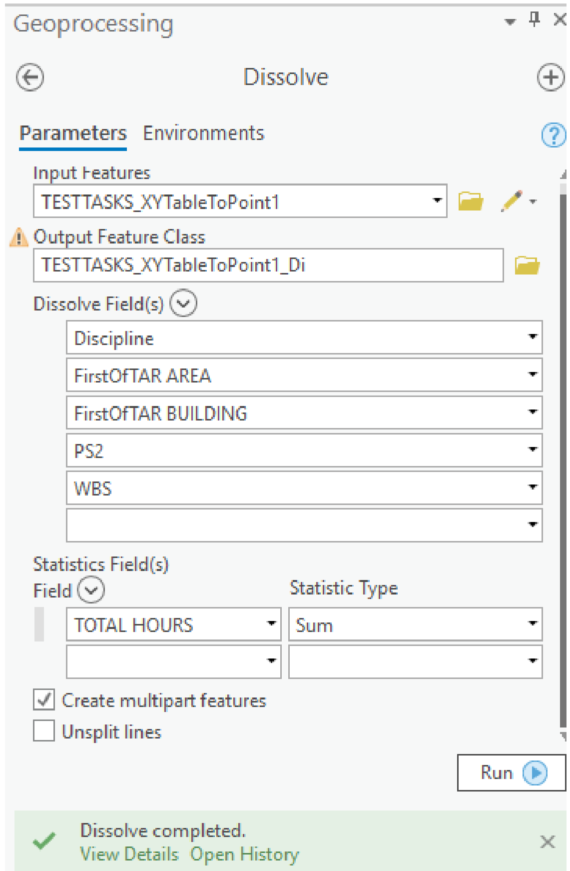

Figure 28 Inputs For Dissolve Tool

5.10. Offset Assignation

At this point, the only relevant query missing is the offset of each point so that the disciplines can be stacked together. Even though the calculation of the offset is quite straight forward the only way to calculate the offset was by first allowing symbol property connections and developing a small macro using the software's internal expression builder as shown in figure 29. The calculation was simple as for each grid in time the total hours where aggregated saving each accumulative addition by discipline. This means for example that the offset of a point representing discipline 9 (Pre/Outside) would be the cumulative labor hours of all other disciplines 1 (Mechanical), 2 (Cat/Cleaning), 3 (Piping), 4 (Elect/Instr), 5 (Rotating), 6 (Inspection), 7 (Scaffolding), and 8 (Support), for that specific grid coordinate and time if applicable. The result was physical points representing a conglomerate of tasks belonging to the same grid area, the same discipline and the same date of execution along with the elevation offset of each of the points in the Z-axis, as shown in figure 30.

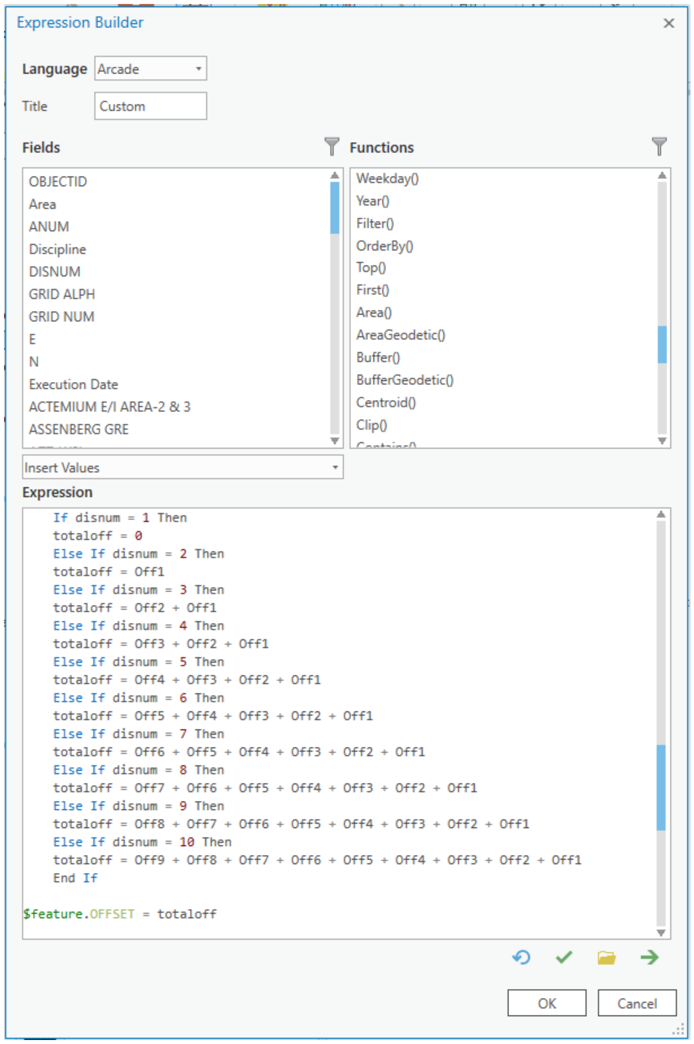

Figure 29 Macro Using The Software's Internal Expression Builder

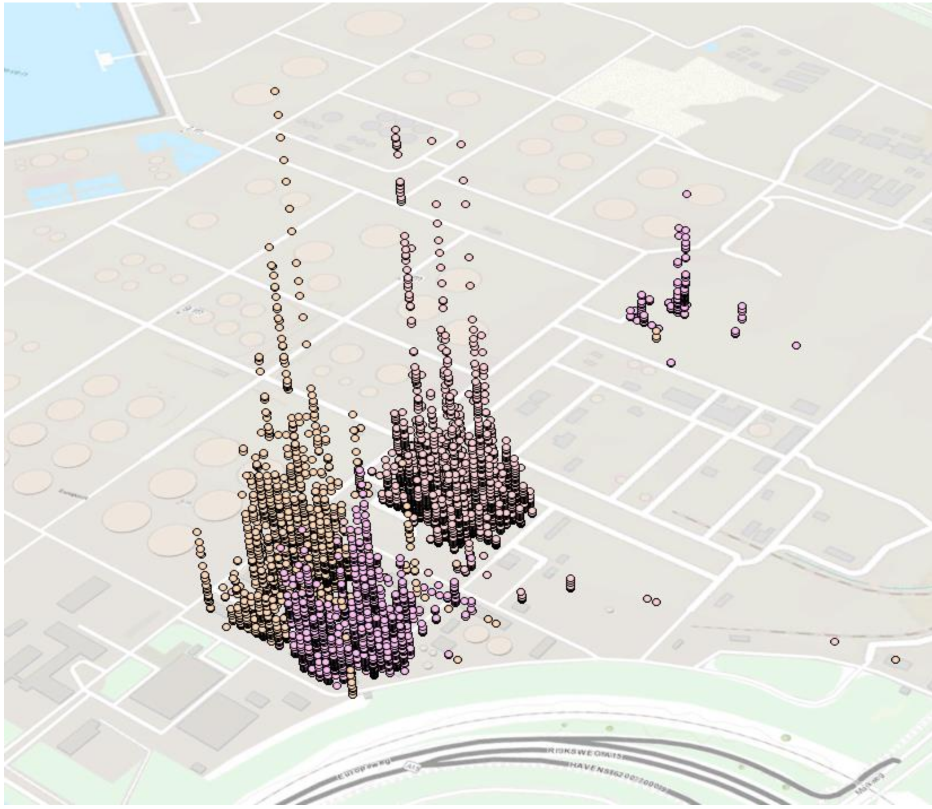

Figure 30 Offset Assignation Results

5.11. Symbology and Temporal data Assignment

With the offset ready, the only thing missing to finalize the visualization tool was the to set the symbology, assign the temporal data, and configure the time slider. For the symbology standing cubes were chosen were the height value was assigned to the labor resources total hours, and the colors were chosen using Trubetskoy's (2017) color diagram. The time was set assuming the PF as a temporal reference and the time slider was configures to show snapping time interval of one day.

5.12. Reflection on the Preliminary Design Process

The result of the preliminary design is appreciated in figure 31, which is shown next to figure 32, the initial proof of concept provided by the client. This was done to show the starting point and final product for the preliminary design phase. Regarding the functional requirements, we can see that an interactive 3D environment was successfully created, assuring that the user could easily navigate through the scene while interacting with the information. Even though the initial scope of the research was to focus the visualization on Area-1, due to the automation and software specific functional tools integrated in ArcGIS PRO visualization could be easily provided for Area-2 and Area-3 as the same operations made for the design of Area-1, were replicated for Area-2 and Area-3 without demanding to much extra work. The Preliminary design has now enough strength to be presented to stakeholders for feedback.

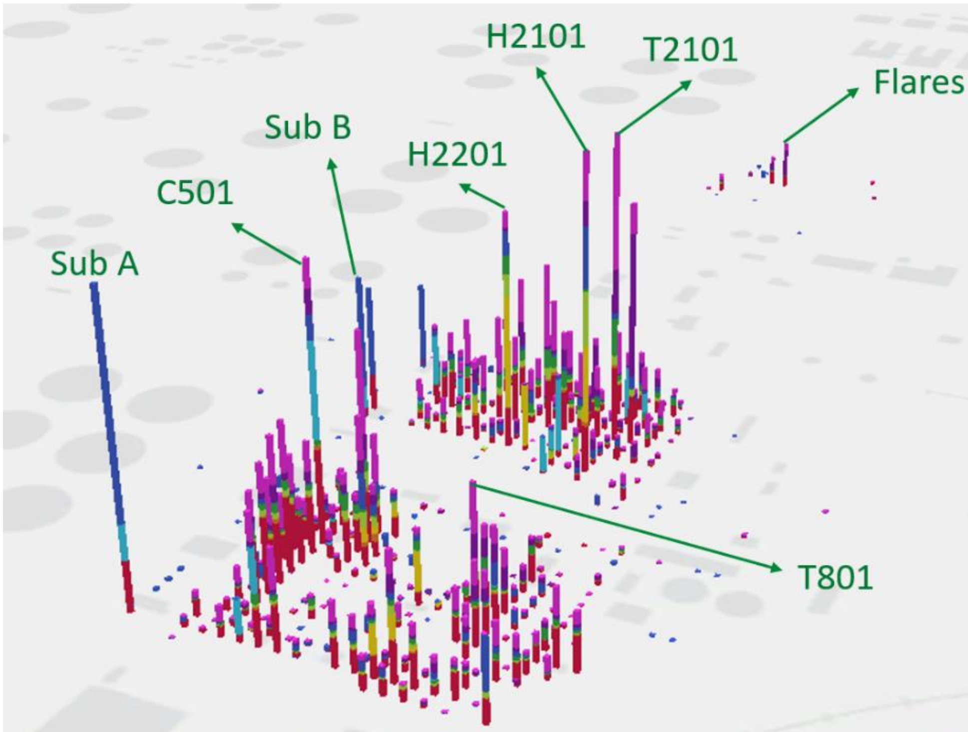

Figure 31 Result Of The Preliminary Design

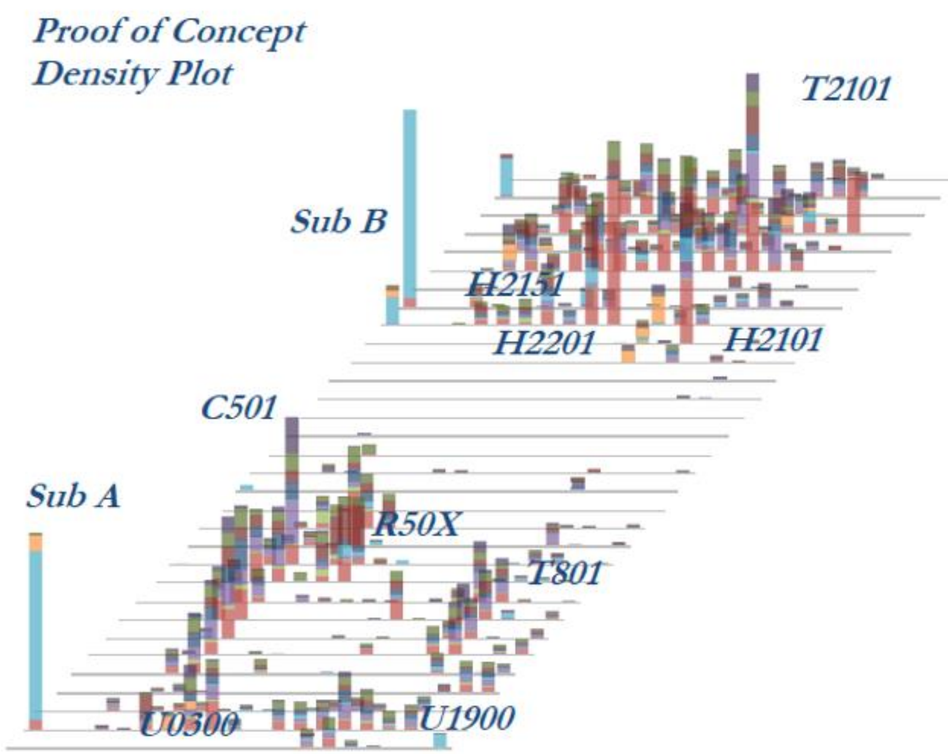

Figure 32 Initial Proof Of Concept Provided By The Client

6. Detailed Design

This chapter will focus on the detailed design phase of the research. Now that the proof of concept has been developed to meet the initial requirements, it is now crucial to fine-tune the design by getting feedback from the relevant stakeholders. In this phase, a focus group was assigned by BPRR to start testing the functionalities of the visualization tool. This focus group was confirmed by the Area-1 Manager, Supervisor-A, and Supervisor-B. Both supervisors were also assigned to Area-1 the most critical area for this turnaround. Due to privacy policies from BPRR, the names of the members of the focus group will not be revealed in the report, and thus the individual members shall be referred to as area manager, Supervisor-A and Supervisor-B. This chapter will then describe the whole feedback process and the consequent changes in the design of the visualization tool. The chapter will be divided into five subchapters, which will revolve around user feedback from the focus group. The first subchapter will be dedicated to the introduction of the tool to the focus group, and the following four subchapters will be dedicated to the functional one on one interviews that were held with each member of the focus group and the findings from each interview round. By functional interviews, it is meant interviews were the tool was provided to the interviewee to allow them to start familiarizing themselves with the visualization tool. Two functional Interview rounds were made, the first round with the individual Supervisors-A and Supervisors-B, and the second a second round with both supervisors and the area manager.

6.1. Tool Introduction

After reaching the desired level of operability for the preliminary phase, the TAR controls manager proposed a focus group of three TAR team members to start testing the user's perception on the tool and to fine-tune the design according to their needs. This was crucial as the focus group are the ones who will be testing the tool during the execution phase of this turnaround. The team members were the Area-1 manager an experienced construction manager with the lead on TAR2019's Area-1, Supervisor-A and Supervisor-B both relatively young professionals going for their second turnaround experience. The supervisors were assigned to Tower T2101 and furnace H2101 components that represented a critical scope for the TAR2019.

Two months before the shutdown and kick-off of the execution phase of the turnaround, the first introductory meeting was held with the focus group and the TAR controls manager. During this meeting, a presentation was made to introduce the concept and the developments made on the tools. The first impression of the participants was on the perspective that the tool provided. The Area-1 manager expressed that in paper, Area-1 seemed much more complicated then Area-2, but given the perspective provided by the tool, it was evident to him that Area-2 would be challenging as well. Supervisor-B directly mentioned that he perceived the usefulness of the tool as he could visualize his scope for the day without having to search for the relevant data or be overwhelmed with the amount of data. Supervisor-A, on the other hand, focuses on pointing out peaks on the labor distribution asking which components were assigned to the picks visualized in the tool. After the meeting, the commitment of the focus group was agreed on, and planning for the first functional interview was made.

6.2.Functional Interviews Round-1

The decision to conduct a functional interview and to work with a focus group was made because of the added value that comes from the consistency and commitment that is achieved by focusing on a small group of very involved stakeholders. Conducting a wider number of surveys was discussed, but both the researcher and the client agreed that only conducting surveys might not bring as much value in the design process as face to face interactive interviews with a functioning tool. The first supervisor to have to participate in the functional interviews was Supervisor-B. During this meeting; a more detailed explanation was given on the functionalities of the tool. After explaining some concepts on the time slider, Supervisor-B straight asked if the colors necessarily had to represent the disciplines and proposed a possible color scheme representing the different contractors. The second comment on improvements for the tool from Supervisor-B was that for his needs, he believes that the complete visualization of Area-1 was too much information.

Curiously enough, the supervisor was asked on the usefulness of the tool. To which he directly answered that the scheduling tools do not provide a good overview of the schedule which goes in line with the literature review done on drawbacks of PM tools. When he was asked how he would use the tool he mentioned that he would use the tool at the beginning and end of the day in order to prepare and focus on activities that might need more attention. When asked on which stakeholders, according to him, could benefit from the tool. His answer that the contractors could benefit from the tool, especially in the first days where there are lots of coordination issues due to the number of people, he also mentioned that most supervisors could benefit from the tool as well as higher managerial positions to get a better overview of the tools. When directly asked if the tool could improve productivity, he said that he was not sure that the tool by itself could improve productivity, he argues that the benefit of the tool is on organizational aspects which might have a causal effect on productivity. When asked on his requirements on the extent to which the information visualized needs to be up to date. Supervisor-B argued that it would be ideal for him if the tool were to be updated in the morning and in the afternoon which is in line with his comment on how he would use the tool, as during the day he would most likely be onsite most of the time.

As talked about in subchapter 5.5 on testing time, there are some variances on the selection of how temporal data can be visualized in ArcGIS Pro. This was brought up during the first meeting with Supervisor-B to get his intake on the topic to do so figure 33 was shown to Supervisor-B so he could assess what the best visualization representation is. The decision discussed was on what temporal data should the visualization tool base itself on. The researcher provided three different options. If the visualization tool is visualized on the PS and the duration of the task is longer than one day, the tool will not visualize the labor resources on the following days. If the visualization tool is visualized based on the PF, and the duration is as well longer than one day, the tool will only visualize the labor resources on the day it must be completed. With these two options, the question to Supervisor-B was whether he would rather see when he had to start a task or when he would have to finish it. He then re-argued that he would like to use the tool in the beginning and end of the day to see both what he had to finish and what he had to start for that day and the coming day respectively. Because of this, it was proposed to distribute the working hours throughout the execution of the project. Supervisor-B agreed that this option would better to suit his needs.

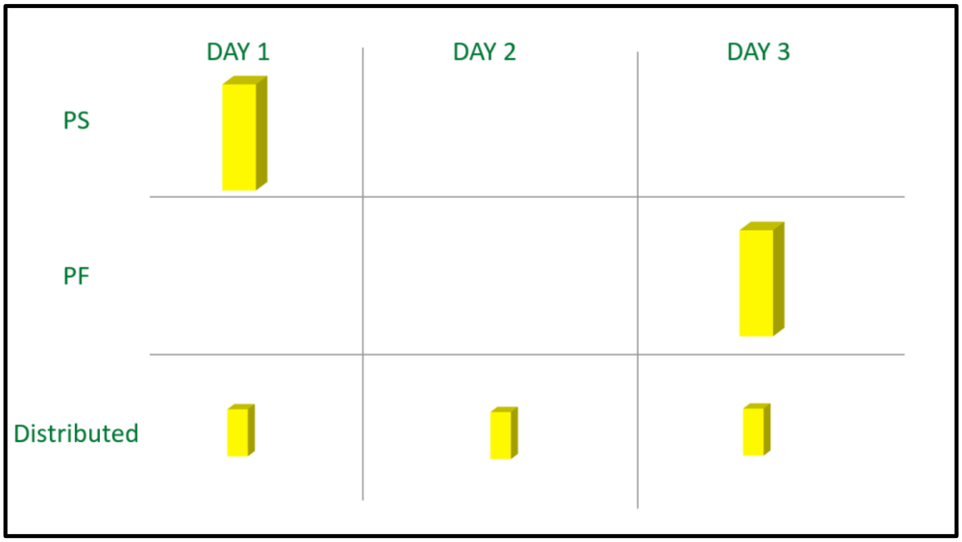

Figure 33 Time Representation Options

The second person to have the functional interview was Supervisor-A, similarly to the meeting with Supervisor-B, the meeting started by going more into detail on the functionalities of the tool. When asked the question on the selection of the time value that the tool will base its visualization on, he also argued that both PS and PF are important to him. With Supervisor-A, it was first noticed that both supervisors were handling very different types of a scope which affects how they plan their day. Supervisor-A argued that the added value of the tool for him is that he can visualize what task is being executed around his scope, and this way has better awareness to plan his scope. Supervisor-A complements this by arguing that in Roser, he cannot filter out scope numbers by location. Supervisor-A also argued that the complete visualization of Area-1 was too much information for his scope. He also argued that he would appreciate more information on the specific contractor rather than the discipline. He also made an interesting statement when discussing the area visualized, as he argued that he is not only interested in his area but the directly surrounding area. He also commented that it might be interesting for him and for the HSSE department on changing labor hours to the number of workers assigned to the task. Supervisor-A asked for more information to be provided on the popup menu.

6.3. Findings on Functional Interviews Round-1

From the Round-1 functional interview, the first assumption was made for this research. Based on the feedback from the supervisors, it is evident that the visualization tool needs to take into account both PS and PF. Because of this, it was assumed that the labor resources for a task with a duration longer than one day, could be assumed to be evenly distributed between those days. The assumption seemed fair according to the TAR Controls Manager.

Another significant finding is that, similar to the case of Primavera P6 were dashboards are customized to fit the needs of the varying roles, the first interview round made it clear that different visualization needs are depending on the OBS. Not only were the different hierarchies affecting the visualization requirements but also the type of scope assigned to the supervisors. Even though both supervisors understood really well the intentions of the tool, we can still pinpoint some differences due to the nature of the scope assigned to them. Supervisor-B has more autonomy over his scope area as he only focuses on two grids, as appreciated in Appendix J, with an important height factor while Supervisor-A had a much larger area covering four grids, as appreciated in Appendix I. There was the perception that Supervisor-A with a higher working area was more focused on using the tool to create awareness of the surrounding activities while Supervisor-B was more reliant on organization and coordination.

Because both supervisors asked for the visualization tool to focus more on their scope extent, changes will be made on the extent of the visualization for their case. This will then require three independent scenes to be created for each person on the focus group adding to the initial scope of this research. For the next meeting, three critical changes were developed, the distribution of labor resources throughout the duration of the task, the focus of the visualization area, and the enhanced use of the Pop-Ups. Because both supervisors commented on the need for contractor information developments will be done in this area.

The changes were implemented for the second functional interview. First, the distribution of labor resources throughout the duration of the task was dealt with. This problem was similar to the calculation of the offsets in the previous chapter, as ArcGIS Pro does not have a specific function for this. It is not a common operation in GIS to divide an event over time, for this specific reason a macro was generated in VBA which has better tabular operation system than that of ArcGIS Pro, the macros can be appreciated in Appendix H. It was also discovered investigating for a solution to this function that ArcGIS PRO has better capabilities and set of tools when directly connected to the database as it has more tools specific for database information retrieval. Meaning that this reliance on VBA will be eliminated once the software is correctly integrated with the different turnaround information systems.

Regarding the problem with the visualization extent and from a comment from Supervisor-A on the importance of awareness in the surrounding area, an idea was generated for the focus on their scope. Given the ability of ArcGIS Pro to easily assign different symbology to layers, the visualization tool can use the dissolve tool to filter OBS by doing so not only will there be a differentiation between Scope area, Grid coordinate, Date, and discipline but also by OBS meaning that now specific scope for the different supervisors can be filtered out and visualized independently. With this done, the researcher found it valuable to visually filter the scope of the intended supervisor from other scopes in his area and again from the scopes in his surrounding areas. This means that the visualization for the supervisors will consist of three independent layers, which will be made evident in figure 34.

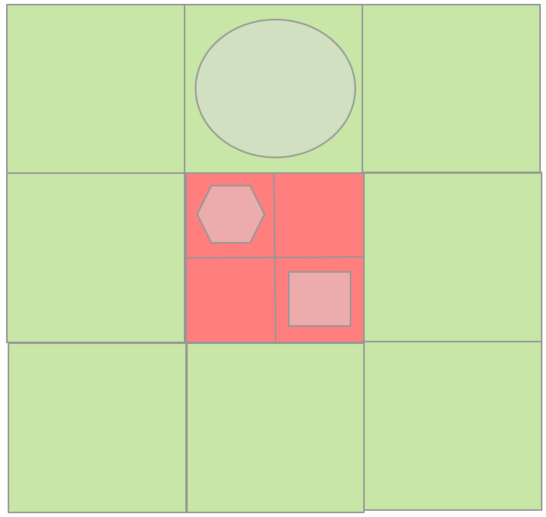

Figure 34 Classification Of The Scopes Surrounding Focus Scope (red)

Figure 34 mimics the grid system where the red square represents the grid where the intended supervisor has assigned scope, the green squares which represent the areas surrounding the intended supervisor. The actual representation of the scope focus for Supervisor-A and Supervisor-B can be found in Appendix I and Appendix J respectively. To represent the supervisor's scope, the standing cube symbol will be used. To represent scope in his area but not assigned to him will be represented with the standing pentagon symbol will be used, and for the scope surrounding the area of interest, the standing cylinder will be used. This way, the supervisors can quickly analyze their scope and their surroundings.

For the Pop-Ups ArcGIS's summarize within tool was used to get the cumulative labor resource by contractor assigned to the supervisor's scope. Figure 35 shows the scene created for Supervisor-A as an example of the new visualization to be presented to both supervisors in the next functional interview meeting.

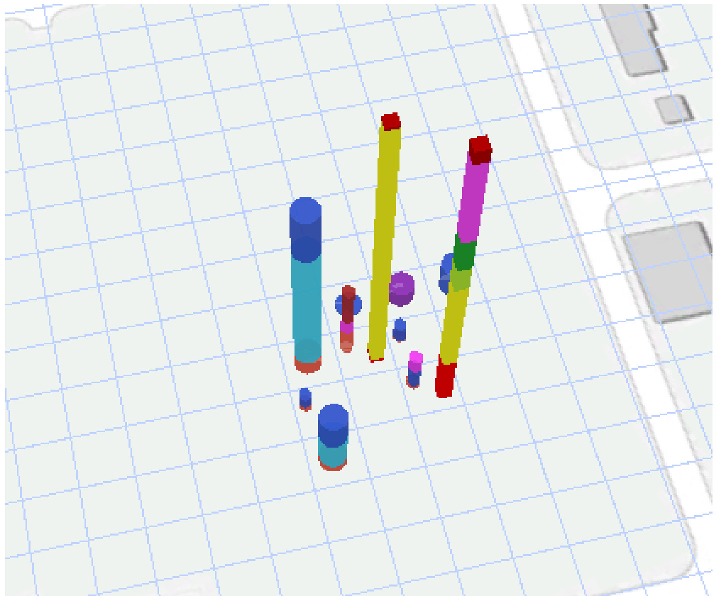

Figure 35 Scene Created For Supervisor-A

6.4. Functional Interviews Round-2

For the second round of functional meetings, the first interviewee was the Area-1 manager. For this meeting, two visualization layers were created the initial visualization with the color categorization of disciplines and the second layer, which took advantage of the dissolve tool's use to filter out the OBS to create a stacked-layer were the colors categorize the different supervisors of Area-1. During the meeting with the Area-1 manager, he was very interested in both layers and the Pop-ups. During the meeting, he pointed out a very interesting note, which was that even though the visualization tool does represent well the distribution of labor, the topographic map did not represent well the refinery layout and argued that a lot of the spatial awareness is lost because of it. He argued that this is crucial to improve the visualization tool and to accomplish the level of comprehensiveness that the research looks to achieve. The Area-1 manager also asked if it was possible to select to filter out a single discipline or a single supervisor within his visualization scene so that he could use for specific meetings were the complete stacked visualization might not be as useful. After discussing the possibilities for the visualization tool, he commented that he sees an important application of these types of tools for HSSE managers to assess hotspots and prepare enhanced mitigation plans. He also commented on the added value that these tools could have on simultaneous operations and the usefulness for the planners in front-end-loading.

Because of the critical feedback provided by the Area-1 manager, changes were made to the visualization of the supervisors before the second interview round. The changes adopted were the actual plot of the refinery layout as the base layer of the map. This was done thanks to ArcGIS Pro's interface interoperability with Autodesk. The CAD layout of the refinery was plotted in ArcGIS Pro by assigning two known and converted georeferenced points, from the BPRR Coordinate system to two polylines in the extremities of the layout. The result of the visualization tool with the refinery plot can be appreciated in figure 36.

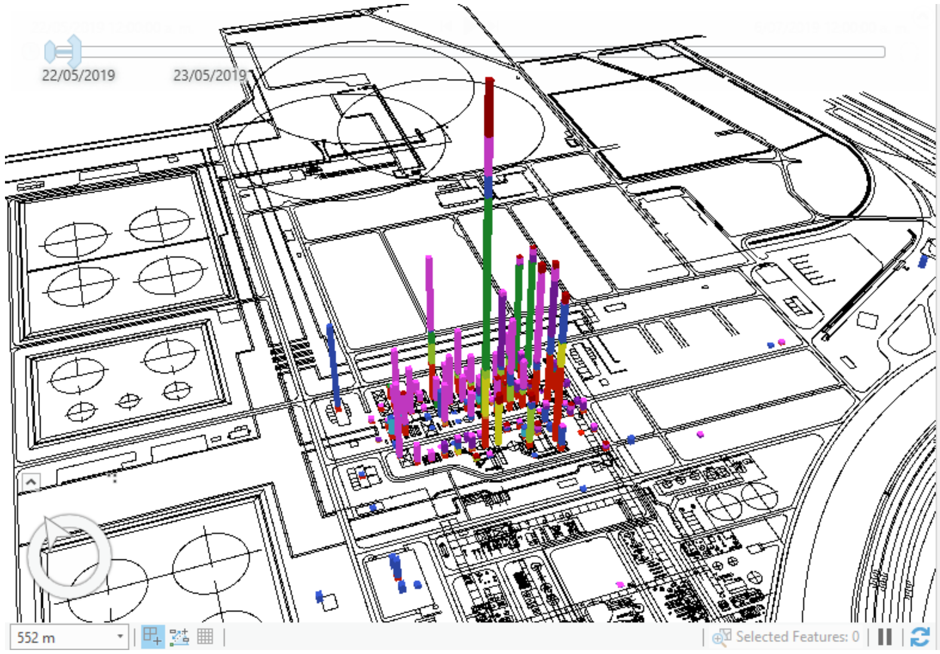

Figure 36 Visualization Tool With The Refinery Plot As Base Map

In the meeting with Supervisor-A, the first part of the meeting was dedicated to the explanation of the new visualization idea, the changes in how time represented, and the new data shown in the Pop-ups. The first question made to Supervisor-A was if his needs were better met with the new visualization layout rather than the old one. Straight away, he mentioned the significant improvement in the visualized data with the layout of the refinery. He also mentioned that focus on his specific area and the differentiation on the own and external goal was very beneficial. Supervisor-A commented on the color use that would aid the visualization. He argued that the surrounding scope and the scope in the same area should have different colors to make his scope contrast even more with the surrounding scope. With the new layout accepted by Supervisor-A, he was asked to make a final decision on three things; the different shapes, for the column that will be assigned to the three layers, the color categorization that he wants to be represented and the aggregated data available in the Pop-ups. Supervisor-A argued that for his scope he would like to use the disciplines categorized by color and the contractors in the pop-up so he can be aware of the type of work he will be supervising and which contractor he has to supervise. For the other two layers that do not fall under his scope, he chose the discipline color categorization as well, but he chose OBS aggregation in the Pop-up. His argument for this selection was that when it is not his scope he would still like to know what type of work is going on in his surroundings, but rather than the contractor he would like to know the supervisor assigned to that task so he could know with which supervisors he would have to coordinate for the day's work if necessary.

The meeting with Supervisor-B went along similarly to the meeting with Supervisor-A. The first section was dedicated to explaining the new visualization layout. To which he considered an improvement from the previous version. During this meeting, the supervisor was more focused on asking questions on how to use the tool. After some time of showing him the functionalities of the tool, it was asked of him to decide on the visualization means regarding the shape selection for the layer, the color categorization, and information exposed in the Pop-ups. Curiously enough he arrived at the same conclusion as Supervisor-A, where he would like to categorize the disciplines by color, and he would like the Pop-Ups for his scope to show him the contractors he has to supervise and for the scope that does not belong to him he would like to the Pop-ups to aggregate on the OBS.

6.5.Findings on Functional interviews Round-2

On the second Functional interviews, the Area-1 Manager gave critical feedback especially with the idea to plot the refinery plot as a base map for the visualization tool which enhanced the visual quality of the tool by a lot especially as it now shows the exact location of the components of the refinery. He also pointed out the benefits that would bring to the tool if he was able to filter out a specific discipline or supervisor that he would like to set focus on. The recommendation on the plot was implemented immediately because the added value to the visualization tool was obvious and benefited the following meeting with the supervisors were both commented on the added value of the plot. Regarding the filtering of the individual layers, this was made possible in one layer by assigning a range to that layer. When trying to implement the second range for both layers of his scope, it was found that ArcGIS only allows one range at a time per scene and given the proximity to the turnaround the layer with the OBS scope was left with the range.

In order to provide the requirements from Area-1 manager, the visualization of the complete scope of the TAR2019 still did not have any ranges set. So the range was assigned to this scene on the discipline category so that if necessary, he or any other interested stakeholder would only have to open the general scene untick Area-2 and Area-3 scope to filter out the desires scope area which, in this case, is Area-1 and activate the range.

To tackle comments from Supervisor-A on color distinction on his scope, the color scheme was maintained, but the symbols representing the scope not assigned to him were designated with a 50% transparency. This was also applied to the similar scene of Supervisor-B which enhanced own scope detection when navigating through the scene.

7. Design Communication

The design communication corresponds to the last phase of the Dym and Little's design cycle and is dedicated to expressing and documenting the final design. This chapter will be divided into three chapters, initially Conclusions on the design process, presentation of the final design, and a section dedicated to communication strategy.

7.1.Design Process

As can be appreciated along with this research there Is and evident transformation of the initial proof of concept provided by the client. Not only is the transformation evident, but each phase of the Dym and Littles design cycle influenced the design process in its own way. Starting with the problem definition chapter, which included an in-depth literature review on the core motivation for the desire to develop this tool for turnarounds, which helped understand the nature of the problem. After understanding why there was a need for such a visualization tool, the conceptual design helped set the functional and operational requirements not only set by the client but also based on a literature review on the uses of GIS technologies as project management tools. The preliminary design shows the testing of the functions required to get proof of concept functioning with the preliminary requirements and the actual step by step guide on how the scenery was constructed. Even though the preliminary design shows a logical process, there was a lot of trial and error involved whilst learning about ArcGIS, GIS technologies in general and the incredible potential and power these types of technologies have. Finally, the design cycle culminated with the detailed design where the tool was tweaked and refined for the specific needs of each of the members of the focus group. Ironically it was in the detailed design where the tool gained its most value thanks to the feedback of the focus group. The Final designed scenes that will be implemented and evaluated in the execution phase of TAR2019 will be presented in the next subchapter.

7.2.Final Design

This subchapter will be dedicated to describing the agreed-upon final design that will move into the evaluation phase. It is initially important to point out that the project was planned for the visualization of Area-1 of the turnaround. The planned scope was exceeded for two reasons, initially because in the visualization process the difference in effort between visualizing the scope for Area-1 and the complete scope for Area-2 and Area-3 was not that different as the same operations were required to visualize the complete scope. The second reason the scope was exceeded was because of the level of specificity that each of the focus group members required, in this case, the level of detail had an effect on the automation and repetitiveness of the visualization process during the execution phase of the turnaround that will be talked about in the limitations in chapter 9. The level of specificity required by the focus group was in line with the finding on the subchapter describing data sources interface and interoperability where it was exposed that the commonly used project management tools found in turnarounds also require a role-based functionality and design.

A total of 4 scenes that are conformed by 11 layers were the final product of the design cycle. All scenes have the same functionality except the General scope and the Area-1 manager scope, which included a range feature in order to filter out the desired specific discipline or supervisor.

the is accompanied by an Appendix where an example of the scene is given. Without further a due, the following tables show the agreed-upon final designs descriptions for the different members of the focus group and the client in general:

- General Scope: Areas 1,2,3 (Appendix K)

Layers	Shape of Column	Color Classification	Pop-Ups
Total Scope Area-1, 2 & 3	Square	Discipline / Solid Color	Contractors

- Area-1 Manager Scope: Area-1 (Appendix L)

Layers	Shape of Column	Color Classification	Pop-Ups
Area-1 Manager Discipline	Square	Disciplines / Solid Color	Contractors
Area-1 Manager OBS	Circle	OBS / Solid Color	Contractors

- Supervisor-A Scope: Area-1 – Focus on H2101 & Surroundings (Appendix M)

Layers	Shape of Column	Classification / Color	Pop-Ups
Supervisor-A Scope	Square	Disciplines / Solid Color	Contractors
Same Grid Area Scope	Polygon	Disciplines / Transparent Color	OBS
Surrounding Area Scope	Circle	Disciplines / Transparent Color	OBS

- Supervisor-B Scope: Area-1 – Focus on T2101 & Surroundings (Appendix N)

Layers	Shape of Column	Classification / Color	Pop-Ups
Supervisor-B Scope	Square	Disciplines / Solid Color	Contractors
Same Grid Area Scope	Polygon	Disciplines / Transparent Color	OBS
Surrounding Area Scope	Circle	Disciplines / Transparent Color	OBS

7.3.Communication Strategy

In order to do valuable research and to get BPRR, workers involved a communication strategy was implemented in order to maximize the outreach and impact of the visualization tool. This communication strategy involved three different tasks. The first task was the participations of the TAR talks. The TAR talks were a writing task promoted by the TAR team were participants were asked to write a short description of what their role is for the TAR2019. Each week the best papers were awarded with gift cards. With the goal of promoting the research and to get interested TAR team members involved, the researcher participated in the second-week competition publishing the paper found in Appendix O. The paper introduced the research, shows an image of the development made at that moment in time and invites BPRR colleagues to get involved in the project. That paper was the winner of the second week TAR talk competition. In the TAR Talks the slogan for the research “Let’s Get Visual…” was implemented, the slogan was used for in all three tasks involved in the communication strategy.

The second task of the communication strategy was writing a user’s manual for the focus group and for any interested colleague as the four scenes chosen for the evaluation phase were made public and accessible within the BP network. This manual included an explanation on how to download and install ArcGIS PRO software, an explanation of the four different scenes available, an explanation on how to find and open the scenes, and a basic explanation on how to navigate and comprehend the interface and the data visualized. The interface explanation includes an explanation of the drawing order to filter data, the time slider to navigate through time in the model with single day step intervals, an explanation on Pop-Ups and the data presented in the Pop-Ups. The manual is presented in Appendix P and was sent via mail to the focus group with each data update reminder. Every time the data was updated in the model, the focus group received a reminder via mail with a reminder message and with the manual attached.

As part of the communication strategy of the TAR2019, a newspaper called "We are TAR" was issued twice a week. The paper is an ongoing tradition in BP turnarounds were, for the complete duration of the turnaround, the newspapers were distributed all around the refinery offices and posted online on the company's website. The newspaper usually contained relevant information on the objectives of the organization, the progress of the turnaround, safety-related issues, and practical information. In the first week of the turnaround, the TAR team communication and external affairs manager requested a small article on the research project to be published in the newspaper for week two. The published article can be found in Appendix Q. The article included a brief description of the research project, an image of the developments made in the visualization tool at that moment in time with its corresponding legend, and open invitation to learn more on the research. This final article played an essential role in the evaluation phase as it grabbed the attention of important stakeholders. This case will be discussed in the following chapter on evaluation.

8. Evaluation

A large part of the research was dedicated to materializing and developing of the visualization tool. Even though this study used literature reviews, interview sessions, and a focus group which covers three of the recommended methods on acquiring knowledge for the design process (Dym, Little & Orwin, 2000). Both the client and the researcher agreed that the best feedback on the usefulness of the tool would be provided by the actual testing of the tool on an actual turnaround. Because of this, this chapter will be dedicated to the evaluation of the visualization tool for the TAR2019. The chapter will be divided into three subchapters, each dedicated to different evaluations conducted on the visualization tool.

8.1. Final Interview & Survey

After the turnaround was finished, the final interview and survey and tool evaluation was conducted on the same two supervisors from the design phase. In these final interviews, the researcher proceeds to ask each supervisor individually a list of question some purely qualitative and qualitative with a quantitative attribute. The complete answer to all the purely qualitative and qualitative with a quantitative attribute can be found in Appendix R & Appendix S, respectively. For the qualitative questions, the supervisors were asked to comment and give his opinion on the question asked. For the qualitative with the quantitative element, the supervisors were asked to grade on a scale from 0.0-10.0 whether they agree or not with the statement where 0.0 represents that they do not agree with the statement question and 10.0 means that they do agree. They were also asked to comment on the reason they gave that score. The questionnaire had two types of question, besides the qualitative and qualitative with the quantitative element. The first type is on general behaviors, and perceptions of integrated turnarounds and the second type of questions are those others directly linked to the visualization tool. The findings from the questionnaire will be described in the following paragraphs and are divided into the previously explained types of questions.

8.1.1. Turnaround General Questions

For the questions evolving the general turnaround, it was found that both supervisors experienced totally different situations as Supervisor-A always mentions problems with the contractor, while Supervisors B argues that at least on his scope the contractors were quite manageable. The reason why the experience varies so much between supervisors can be directly linked to the nature of their scope one supervisor was working on furnaces in a dispersed area while the other was working in a tower which meant that his area of work was more reduced. Also, Supervisor-A mentions that he had to work with many different contractors, while Supervisor-B said that he had to deal mostly with one contractor assigned to the tower. Because of this, it is clear why both experiences were different. Regardless of their difference in scope, and the fact that they value the visualization tool for different functions, their answers evidence that both perceive a gap in the visualization of data.

One of the things they both agree on in the qualitative questions is the uncertain nature of the turnaround as both mentioned that turnarounds are lived day by day and planning to far ahead would be useless as there is always something changing which cannot be accounted for. Supervisor-B gives an example of scope change for the tower in question four on the problems they encounter during the TAR2019. Supervisor-B said, "When we opened the bottom section of the crude tower, we were expecting to clean solid, but when we got there it was very sticky and only because of that it took a lot of time." This is an excellent example of how an activity not necessarily technically complex got delayed because of the uncertainty of the scope. This is consistent with the literature review on turnaround complexities in subchapter 3.3.2 were one of the main complexities of turnarounds was scope uncertainty. Scope uncertainty has a very negative effect on communication and coordination as the constant changing of conditions, and increasing scope makes communication and coordination very difficult. Currently, there is no implemented information system that represents the instant condition of the progress of the turnaround. Making it very difficult for information to reach the stakeholder in time, which causes coordination problems and increases the chances of task conflicts as it will be tough for contractors to follow the base plan to the letter if they already started with the wrong foot.

Another interesting finding was on question two, and question three of the qualitative section where it was evidenced that both supervisors attribute the wasted time in labor productivity to the contractors not using their time efficiently, communication and coordination problems caused by lack of experience in refinery setting or lack of skills. This makes supervisors jobs more complex as the Supervisor-A argues in qualitative question two, on the complexities of turnaround projects that make it difficult to follow the base plan, "The number of contractors. All the different contractors want to do their job and are going for it, but if contractor activities are conflicting, they argue on who should do the task first. It is the supervisor's job to say what the priority is and who should wait."

Regarding the qualitative questions with the quantitative grade both supervisors seem to agree on various fields, they both consider that Roser or Primavera P6 are lacking in the simplicity in the way data is represented. Also, both of them feel that those systems have too much information that makes it hard to interpret. The supervisors scored the lack of spatial data on currently used PM tools for turnarounds with an average of 6.5, meaning that they do agree that primavera P6 and Roser lack in data visualization interpretability and accessibility. They both feel that these commonly used tools have overwhelming amounts of information and are not very user-friendly based on the comments for quantitative question one. The comments from both supervisors on the reasoning behind the score they assigned are related to the findings from the literature review on the drawbacks of PM tools touched in subchapter 3.3.6. This is evidenced in the following fragments from supervisor-A and Supervisor-B respectively "Too much information, I have to export data to excel, and I have to delete a lot of useless information." and "I do not like the schedules that are in primavera for me it is too big, and there is too much information for me. To check the data, you really need to dedicate some time to understand what you are looking at."

Question two on the awareness on the external scope within the same grid area the average score was 5.0, meaning that they are not entirely aware of tasks to be executed in their area by other supervisors. Interestingly enough they mentioned that even though they should have been aware they were too busy to really focus on things outside their scope, and they should only focus on doing their job correctly and hope that their colleague does his scope correctly as well. Interestingly Supervisor-B argues that information comes from talking with other supervisors and colleagues rather than checking Primavera P6 or Roser. This proves in a way that the information communication technology strategy from BPRR is not covering all the gaps in the supervisor's needs.

The argument here is that if supervisors exchange relevant information talking rather than using the PM tools which are information communication technologies, it means that either the current PM tools are not fulfilling the needs of the supervisors or that the supervisors have not received proper training on the PM tools. The reasoning behind this argument is twofold, first the massive amount of information that is flowing within the turnaround organization (Redwood et al. 2017), which would make it very difficult to capture and communicate all this information verbally and correctly, having in mind that computational PM tools are available for the project. Second, the findings from Cormier and Gillard (2009) research where they evidence that due to the intensified fragmentation experienced in turnaround projects; the implemented information system should not only consider the needs of the owner but also the destination audience which varies widely in terms of craft, experience, and level of responsibility. This argument represents a gap because as previously mentioned, either the supervisors are not using PM Tools correctly or that the available software is simply not covering all the supervisor's needs. In either case, there is a clear gap in the use of data visualization technologies.

On the quantitative question three about the perceived coordination problems during turnarounds, the average score was 7.5 in this question; both of them mentioned that the cause of this coordination problem is the contractor. This answer is also in accordance with the literature review where it was evidenced that the higher the amount of work outsourced the higher the organizational complexity, as more effort needs to be made by the client to assure the desired schedule, quality and safety performance level from the contractor.

Regarding communication problems during the turnaround in quantitative question four, both supervisors gave very different answers. Supervisor-A says that communication problems depend on whom they work with, like for example, working with people from different nationalities that do not speak the local language. He gave this question a score of 6.0, meaning that he believes that turnarounds do have a slight communication problem. On the other hand, Supervisor-B argues that he did not have problems, but he attributes that to the fact that his scope was focused on the tower T2101 meaning that they were not as many turnaround personnel or supervisors conflicting with his scope. Another point is that Supervisor-B seems to be on top of communication or at least understands the importance of communication as his comment on the quantitative question four were he commented “I am always talking to everyone sending emails. Communication is a very important factor”. This response is also aligned with the subchapter 3.3.3. On the Importance of organization, coordination, and communication in turnarounds.

Both the qualitative and the quantitative questions on the turnarounds in general, two important things have been found; First, how the findings in the literature review and the answers to the questions on behalf of the supervisors are validating each other. This has been evidenced in this subchapter within the analysis on the supervisor's answers, and the various links made between their answers and aspects of the different literature reviews that compose this report especially the literature reviews in subchapter 3.3. on the nature of the client's problem. Second, the awareness on behalf of the supervisors that there is a gap in the current information communication technology used to visualize data or at least the awareness of the massive room for improvement in data visualization interpretability and accessibility. The developed visualization tool seems to cover this gap. With an analysis of the final interview and survey evaluation on the visualization tool on behalf of the supervisors, that will be presented in the upcoming subchapter, the supervisor's feedback on the visualization tool will provide better insight on the usefulness of the tool.

8.1.2. Visualization Tool Questions

Regarding the questions specific to the visualization tool, both supervisors seem to agree more on their views if compared to their answers on a turnaround in general. In the qualitative questions, both supervisors agree on the usefulness of the tool as they like the overview perspective and simplicity in which the information is displayed. When asked if the extent to which the tool is usable, both of them agreed that the tool is relatively easy to use were both supervisors were able to navigate through the model and obtain the desired information.

Supervisors were asked how they would use the tool and how would it be different from their common routines. Supervisor-A said that he would use the tool to prepare the workload for the following days. He also mentioned that normally he would have to search for the task in Roser. He also emphasizes on the added value of being able to visualize his scope and the other supervisor's scope in his area or surrounding that might affect his work. Supervisor-A then agrees that the tool generates spatial awareness of the surroundings, which, according to him is crucial when considering simultaneous operations.

On the other hand, Supervisor-B, regardless of agreeing on the added value of the overview or general perspective that the visualization tool provides, argued that given that his scope was in a small area and not conflicting with as many contractors and supervisors as Supervisor-A, the tool is much more useful when the scope is dispersed. These findings are also aligned with his responses on the previous section on the general turnaround's questions. His argument is also logical as appreciated in Appendix I and Appendix J showing the focus area of both supervisors where it is evident that Supervisor-B's scope is centered in the tower whilst Supervisor-A's scope is more dispersed.

When asked about which stakeholders would benefit more from the tool, both supervisors mentioned the contractors. The reasoning behind their argument is that supervisors are BP employees and therefore are familiar with the refinery on the other hand contractors which vary widely in discipline, working culture, background and experience will not be familiar with the refinery and could benefit from the location provided and the simplicity of the data visualized by the tool. Supervisor-A mentions that schedulers could also benefit from the tool as the visualized scenery would provide a better perspective for leveling resources. Supervisor-B argues that the tool would be very useful for the management team as with the helicopter overview that the tool provides and the connectivity with other PM tools, they monitor and benchmark the progress from their desk and make fast decisions when they detect delays or lagging activities.

When asked how to improve the tool for future turnarounds, Supervisor-B did not see how the tool could be improved. Supervisor-A remarked that the visualization tool should be applied on a general level, including area managers, supervisors, and contractors. He argues that by implementing on a general level, the benefits of the tool would be much more evident. Even though this is not an improvement of the actual tool but rather a proper implementation of the tool in the organization, his argument is valid especially taking in to account the fragmented characteristic of turnarounds which requires exceptional collaboration in which information should cascade through all relevant stakeholders.

As the model does not visualize the refinery elements in 3D, one of the worries when designing the model was the lack of differentiation on the height where the task should be executed. When asked if the tool should differentiate tasks by the height they are executed in, both of them argues that it was unnecessary. Even Supervisors-B that worked in a tower, which has a critical height component, argues that regardless of working in the tower work preparation are generally made at the base level.

Finalizing the qualitative questions on the visualization tool, the supervisors were asked if they perceived that the tool could be useful for other application or in other phases of the turnaround rather than the execution phase. Both Supervisors argued that the tool would be beneficial in the planning phase, especially in the resource leveling, which is aligned with the findings in the literature review on the uses of GIS application in PM. Also, regarding the different phases the tool could be applied in, Supervisor-A was really enthusiastic on the 4D earned value analysis, which will be touched on in the subchapter on earned value analysis. Regarding the other applications, they argued it would be useful for work preparation and resource planning. Supervisor-B argued that HSSE could be a useful application of the tool as hotspots of intensive working areas are evidenced in the visualization tool.

Regarding the graded qualitative questions for the evaluation of the visualization tool. When asked if the tool had the potential of replacing the other tools used for the turnaround, they both gave it a score of 0.0 meaning that they do not see the visualization tool replacing any of the used PM tools. They both argue that the type and level of detailed data that is usually stored in Roser would be hard display in the visualization model. This question is important because it evidences that both supervisors understood that the visualization tool serves as an overview and depends on the information provided by Roser and Primavera P6 to visualize its data as presented in subchapter 4.3.3. on Selection of Software.

Similar to the qualitative question on the problems the supervisors found when they used the tool where they answered that they did not find any, the supervisors were asked to grade the visualization tool on user-friendliness and the quality and simplicity in which the visualization tool presents its data. For this question, the average score was 7.5, where both argue that information is clear and does not need much detailed analysis as the color classification and the information provided by the Pop-Ups is straight forward.

When asked if the visualization enhances coordination, the average score was 7.5. Supervisor-B scored the visualization tool on enhancing coordination with a 9.0, arguing that the potential to improve coordination is very significant. However, he argues that the only way to achieve this improvement on coordination Is by implementing the visualization tool on an organizational level, which is very similar to the answer provided by Supervisor-A in the qualitative question on how he would improve the tool. Supervisor-A commented that rather then scoring the tool with a 6.0 on coordination, he would pump the grade up to 8.0 only if the visualization tool is implemented in the planning phase. This has become a recurrent argument not only by the supervisors but also in the literature review in applications of GIS in PM where there is evidence that other researchers successfully implemented GIS technologies for PM tools in the planning phase. With Supervisor-A's 8.0 score, the average score of the tool on enhancing coordination would now be 8.5.

When asked on enhancing communication, the score was 7.5, but Supervisor-B argued that the true potential of communication enhancement would only be evidenced if more people are using it. This argument has also been recurrent in the answers of the supervisors, which is expected because to see the effect of the tool on integrated turnarounds truly, it should be implemented on an organizational level as previously mentioned. Supervisors gave the highest average score from all the questions in the whole interview on the spatial awareness that the tool provides were they assigned an average score of 9.5 as they argued that the spatial awareness provided was the best quality of the tool. Supervisor-A compares the spatial awareness provided by the visualization tool with google maps. Supervisor-B highlights that he is not aware of other tools that provide the same service.

The last two questions of the interview asked if the supervisors considered the visualization tool helped reduce wasted time and if it improves labor productivity. Both questions got a score of 7.5. For the wasted time both supervisors considered that the tool would help, Supervisor-A highlights again the potential the tool has if made accessible to the contractors. Supervisor-B argues that the tool provides an overview of where you have to work which if made accessible, should reduce wasted time. For the question on labor productivity, both supervisors answered with recurrent arguments saying that the tool does have the potential to enhance productivity but to unluck this potential, it should be fully implemented. From the questions evaluating the tool, it can be said that it scored reasonably high even though remarks were made that the supervisors as users did not require the tool as much as other stakeholders like the contractors. Also, recurrent argument in their answers mentioned the application of the tool on planning phase for resource-leveling and front-end loading. These findings were expected because as the use of GIS as PM tool for integrated turnarounds is very innovative and almost unheard off, this research is still in the development phase this and can be seen as a small step in achieving a visualization tool that can be implemented on an organizational level and integrate it into the common processes.

8.2.Mistras Case

As mentioned in subchapter 7.3 on Communication strategy, the TAR team communication and external affairs manager requested a small article on this research project to be published in the "We are TAR" newspaper. The article is presented in Appendix Q. The publishing of this article in the "We are TAR" newspaper, which was distributed all around the refinery offices, and posted online on the company's website, grabbed the attention of important stakeholder. Somedays, after the article was published, Mistras Group, an international Non-destructive testing and inspections contractor, sent a request asking for the provision of a visualization scene visualizing their scope. As they were contracted for their nondestructive testing (NDT) services, the nature of their scope had particular circumstances that required them to be very location-time driven. NDT services in the oil and gas industry provide nondestructive testing of the different elements like pipelines, tanks, rigs, and a wide variety of different elements. These services are used to test the inside state of the element without damaging it. The problem with these services is that they use technology that emits radiation, this implies that when they must execute their tasks, they must take extra safety percussions due to the hazardous environment generated. This is critical during a turnaround because there are so many people working in the same surrounding area that they must be extra efficient, and location-time driven to get their tasks completed in a safe manner and without affecting other working areas. This is even more problematic as their scope was dispersed through Area-2 and 3, including the flares. They requested the tool because they were having problems coordinating their tasks and considered that the visualization tool was an excellent way to tackle their challenges.

For their scene, they requested a color categorization in the resource's category, which as appreciated in the data description on section 5.6 of this research it is a simple subcategorization of the disciplines. Their final scene can be appreciated in figure 37.

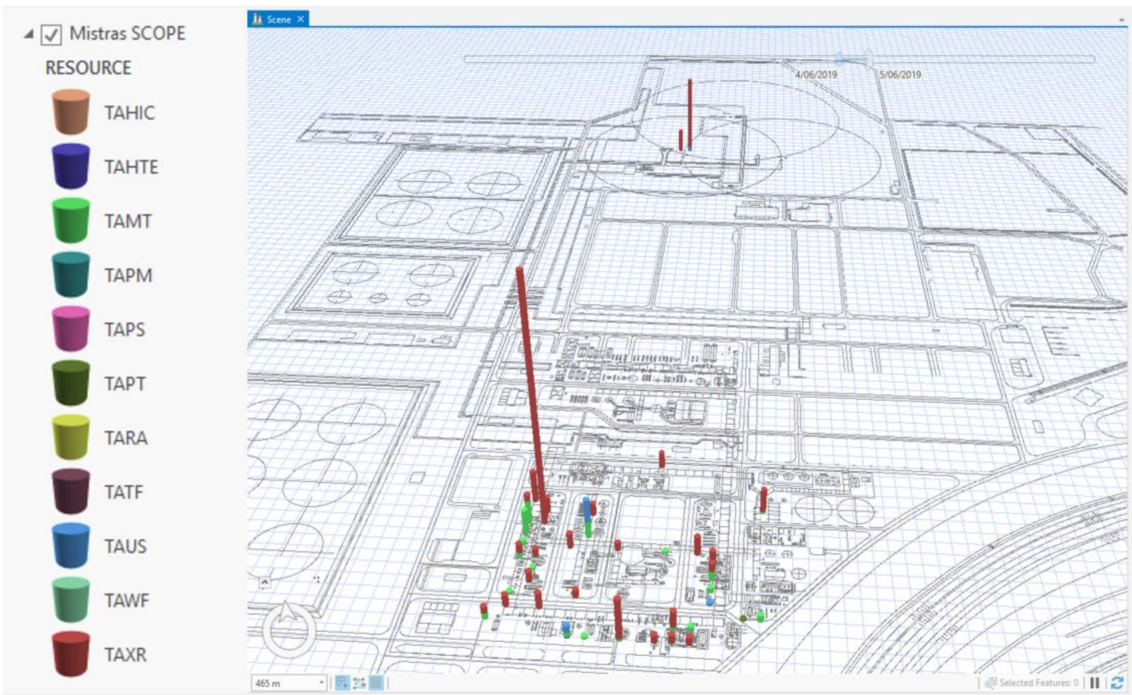

Figure 37: Representation of the scope for Mistras

Two updates were made for Mistras Group until it was announced that they were going to be let go. Unfortunately, they were let go before any feedback was given on the tool. However, for the visualization tool, which is still in the development phase, the fact that external parties see the added value and requested the visualization service for the use during a real-life turnaround in the middle of the execution phase is regarded as very positive feedback. The reason why this is taken as very positive feedback is that with the communication strategy the visualization tool was put on the market and received its first client external to BPRR which shows that stakeholders do perceive the added value of the visualization tool.

The Mistras case is also very interesting because it was a contractor that requested the service. This is interesting because, until this part of the research, it has been found in the literature review demonstrates that turnarounds are profoundly affected by fragmentation and by the inexperience with the site on the contractor's behalf. The research has also found through functional interviews and evaluation interviews on professional supervisors, that their thoughts are aligned with literature which validated the results on both sides. So, with the supervisors and the literature review, two sources share the same perspective. Now with the Mistras case, a proper contractor has demonstrated during the execution of the turnaround not only that fragmentation affects turnarounds as well as the inexperience of external contractors but also aligns with the recurrent arguments given by the supervisors on the potential the tool has on if applied on contractors.

This experience will be taken as positive feedback for the visualization tool as it proved that contractors do need better orientation and coordination during turnarounds and that the visualization tool has the potential of providing that gap. Which as previously said also goes in line with the results from the survey on the supervisors were they both argue that the benefit of the spatial awareness was much more needed for the contractors rather than the supervisors who are BPRR employees and therefore familiar with the Refinery.

8.3. Earned Value Analysis (EVA)

An earned value analysis was done for both supervisors to see how they performed during the turnaround. First, it is essential to point out that due to the difference in both the supervisor's scope, both EVA are not comparable. An earned value analysis represents graphically the difference between the base plan schedule and with what actually happened in the field. For Supervisor-A, it was observed that for some time he was on tops of schedule, which is actually exception given the turnaround environment, as seen in Appendix T. This is slightly mentioned in his response to question five, where he comments that he knew which activities were more critical and that he was focusing on these activities working in front of the plan. Regardless of this, doing a gap analysis, it was found that Supervisor-A was lagging a maximum of 1500 hours on the 6th of July. 1500 hours is a significant amount of time lagging compared to the grand total of 8950 hours that were assigned to his scope. It is also important to point out that the productivity for his scope cannot be all pinpointed to him as it involved various contractors and many different factors which he cannot be accountable for.

On the other hand, Supervisor-B might not have been on top of the schedules appreciated in Appendix U. However, his gap analysis shows that the max amount of hours lagging was 400 out of the 4246 hours assigned to his scope. The Earned value analysis of Supervisor-B was, therefore, much more stable than Supervisor-A. But, then again, multiple factors come into play with the earned value analysis. So, for both supervisors, it can be argued that due to the wide variety of factors that affect their scope it would not be a good conclusion to assume that the lag or earned value is directly caused by their one work. This also means that the effect of the visualization tool cannot be measured from these earned values. This will have repercussions when proving the hypothesis in the conclusions

Because of this reason, it was discussed with them that regardless of how much influence they had on the EVA, they were still interested in the trends it showed. Taking advantage of the already designed visualization tool. A 3D earned value analysis was provided so that trends that the earned value analysis provided can be followed in a 3D environment which also uses the same color categorization as before allowing them to track progress by discipline which opens up a new horizon to possible uses of the tool. Supervisor-A in the questionnaire when asked where he thinks the tool can be applied, he mentioned the 3D EVA which according to him lets him see in what days and under what contractor a discipline lags of the EVA are represented. Figures 38 and 39 show the visualization of these 3D Earned value analysis.

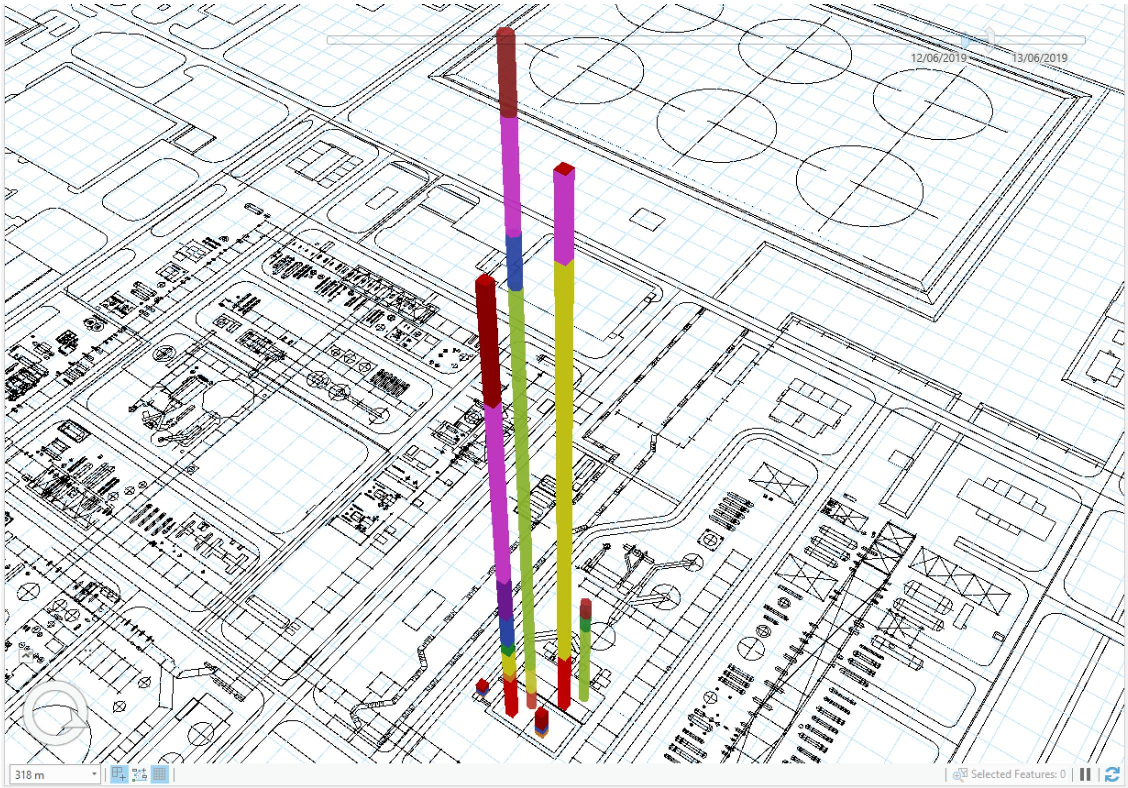

Figure 38 Supervisor-A 3D EVA Standing Hexagon Represented Planned And Standing Cube Represents Actual

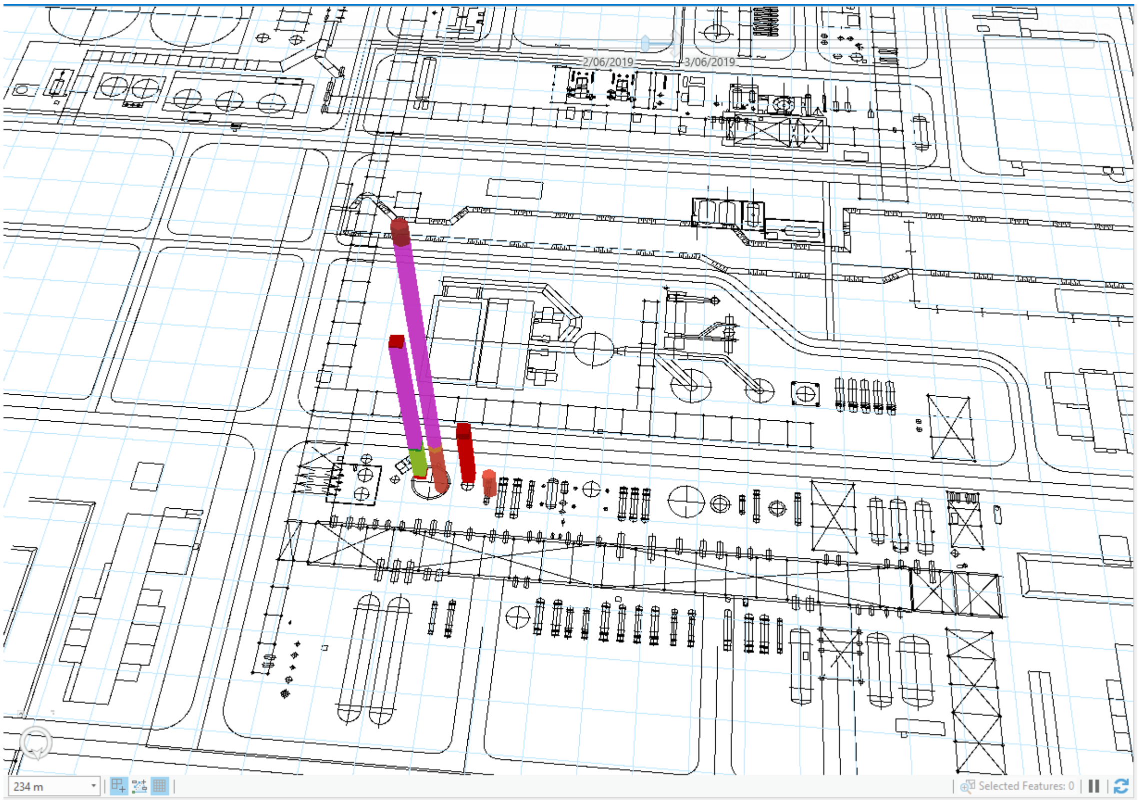

Figure 39 Supervisor-B 3D EVA Standing Hexagon Represents Planned And Standing Cube Represents Actual

9. Conclusions, Discussions and Recommendation

The final chapter of the research will be divided into five subchapters dedicated to the conclusions, limitations of research, the recommendation to the company, the recommendation to future researchers, and personal reflection. In the conclusions, the sub-questions and main question will be answered as well as proving the hypothesis. In the limitations of the research, the limitations encountered through the research will be listed and discussed. The recommendation to the company will express based on the researcher's opinion of how BPRR should proceed with this research. For the recommendations to future researchers, the researcher will provide different research possibilities that have arisen from this thesis. The chapter will conclude by presenting the researcher's personal reflection on the research.

9.1.Conclusion

The conclusions to this research will be presented by answering explicitly the research questions of the research and based on that either accept o negate the hypothesis statements.

SQ1: Why would labor productivity, during the execution phase of the turnaround, benefit from the integration of schedule, labor, and geospatial data into a visualization tool?

The literature review starts by introducing turnarounds and their relevance to the industry. This is an essential point to take into account because turnarounds are so crucial to the industry that according to the literature review, that turnarounds are massively important to the company's competitiveness, sustainability, and profitability. It is important to point out that up till now, it has not been argued that turnarounds are unproductive. The situation with turnarounds is that they are affected by many variables that keep adding up to the complexity of the project, which in the end may cause a negative effect on the result of the turnaround. Given that Turnarounds are so important, and as the oil gas industry is characterized by its competitivity and volatility, which is the reason why BPRR is consistently trying to improve their processes and make the business sustainable. In recent years there has been a drive from companies to achieve sustainability through productivity. This drive refers to the idea that by using resources more efficiently, BPRR will reduce wasted resources and therefore bring a competitive advantage to the company. These arguments evidence the desire of BPRR to maximize labor productivity.

The massive importance of turnarounds has consequences on the internal strategic pressure on successful and fast execution of turnarounds. From this point on, there is a ripple effect that continuously adds organizational complexity to the turnaround. For example, due to the high internal strategic pressure, turnarounds become highly schedule driven and must be executed in short timespans in order to minimize production loss. The amount of different technical disciplines, interfaces between disciplines, amount of outsourced work, dependencies between tasks, size of projects among others are all complexities characteristic of turnarounds and categorized as organizational complexities as exposed by the literature review.

This high internal pressure has diverse effects on the complexity of turnaround, like the fact that turnarounds are highly schedule driven. The high internal pressure mixed with the fact that the execution of turnaround requires a wide variety and amount of personnel to cover all the different disciplines and tasks that must be executed. The fact that so many people are needed from very specific disciplines makes it is complicated for the client or any single agency to be able to cover the scope of the turnaround. This obliges the client to outsource most of the scope to multiple contractors, which bring even more difficulties because each contractor will have its own working culture, its own information system, and its own common processes. All of these aspects make turnaround highly fragmented. The problem with fragmentation, as exposed as well in the literature review, is that it creates barriers and operative island that make it difficult for projects to reach the desired level of collaboration. Where fragmentation exists the integrity of the team is lost having more negative effects on the level to which communication, coordination, and decision-making cascade through all parties and individuals with a fluency which has the potential of affecting productivity negatively. Demanding extra efforts from the client to promote and maintain the desired levels of collaboration, coordination, and communication.

The literature review has also evidenced that given the high level of fragmentation and the vast size of the personnel, it is no longer possible to tackle these complexities easily. The literature review then touches on Information Communication Technologies where it was found that different researchers propose to tackle these complexities with the implementation of a state-of-the-art information communication technologies as they argue that the implementation of a structured knowledge transfer system can improve the success of any turnaround drastically. By implementing such a system that assures that information cascades through the multitude of parties involved in turnarounds, there is an improvement in the consensus of information available which enhances coordination. Taking this into account and the analysis done on the drawback of PM tools, which proves that scheduling tools are not easily interpretable and challenging to visualize especially as they use pert and Gantt charts. On the other hand, BIM technologies are more oriented to the design phase, the modeling of the physical elements of the structure, clash detections, and 4D simulations. As in turnarounds, it is the organization aspect which is complex the literature review. BIM does not cover the needs of the turnaround.

To sum up, the literature review shows that turnarounds are truly complex at the organizational level. Based on the literature, it has also been said that information communication technologies provide enhanced communication and coordination. However, there is a gap in the common project management tools on the management and control of labor resources. If this is implemented and the data visualization tool is accessible, easy to interpret, and Is adequately integrated within the organization, it is evidenced in the literature review that this tool will improve coordination and improve communication. With increased coordination and communication of information that cascades through all relevant stakeholders the visualization tool should have a positive impact on the labor productivity as all stakeholders are more coordinated and relevant information is cascaded to them which means there is more awareness on what’s going on which is vital especially due to the dynamic scope of turnarounds. Not only awareness of information will be improved, but also spatial awareness, which will help decrease the wasted time by workers unfamiliar with the refinery.

SQ2: Which visualization technology better suits the integrated turnaround's needs?

The starting point when choosing the visualization technology is analyzing data sources, interfaces, and accessibility. So, starting with the data source, it has been found that BPRR uses ERP systems as their central database. Regarding PM Tools for a turnaround, BPRR uses Primavera P6 and Roser Suits as exposed in the subchapter 4.2 on data sources, interfaces, and availability. Given this and the requirements set by the client, which specifically require for the visualization tool to be interoperable with the different PM tools. So now it is evident that no matter what technology Is chosen, we must make sure that it follows the requirements. Doing an investigation on Roser and Primavera P6, it was found that both allowed connection to the database Roser using SQL database and Primavera P6 which uses an interoperable API or through its oracle database. Leaving aside the interoperability for a while and focusing on the functional requirements it the client requirements are that the tool must work with 3D geographical domain and that navigation is possible through that domain. After an investigation on the possibilities, geographic information system (GIS) technologies allow flexible and interactive visual representations of data and uses a georeferenced database as its source of information. Given the requirements set, GIS seems like a proper tool for regrouping relevant information and visualizing data in a more interpretable and accessible format.

From these aspects, it can be concluded that there is enough background information motivating the use of GIS technologies to tackle the requirements for the visualization of labor resources set by the client. So yeah basically to sum up given that GIS technologies can connect to databases assuring that the technology provides la interoperability with the PM tools found, also the fact that some GIS technologies work in a 3D environment and use georeferenced database.

Ironically as appreciated in section 3.1.1 on the description of the client, the oil industry is divided into upstream and downstream sectors. Even though BPRR belongs to the downstream sector, all BP subsidiaries have a general organizational software licensing program. After selecting GIS technology as suitable for the visualization tool, it was found that the client organization had to license for ESRI software, which is used in the upstream sector of BP plc for basin and topographic analysis. Environmental Systems Research Institute (ESRI) is the market-leading developer of GIS technologies meaning that the software's offer would be the top of tier reassuring that technology chosen is the best suiter for the integrated visualization. The interoperability flow diagram with ArcGIS Pro seen in figure 7 evidences the interoperability options with either Primavera P6 or Roser.

SQ3: Do the stakeholders appreciate the visualization tool as a tool that enhances coordination and communication during the execution phase of the turnaround?

For this sub-question, the findings in chapter 6 on detailed design and chapter 8 on evaluation were used as these chapters contain all interactions with stakeholders. Initially, regarding findings from chapter 6 on the detailed design, straight away when asked one of the supervisors on the usefulness of the tool he argues that scheduling tools do not provide an overview of the schedule with georeferencing. On the other hand, he argues that the developed visualization tool does provide, which means that the developed tool proven to fill a gap at least thanks to the overview and the easy interpretation of the data. When asked on the stakeholders that could benefit from the tool, he argued that the contractors, especially in the first days of the turnaround because they require some time to coordinate themselves and get to know the place. It was also found in chapter 6 that supervisor A with a larger working area he was more focused on generating awareness, meaning communication wile Supervisor-B was more reliant on organization and coordination. This also shows us how the visualization tool or any technology intended for similar things will have to be role dependent. With these comments, we finish chapter 6 and jump to chapter 8, which has much more interactions than the previous that.

Chapter 8 corresponded to the evaluation phase of the tool on behalf of the supervisors show a score of 7.5 for the usefulness of the visualization tool where the supervisor-B on coordination scored 9 with the comment from Supervisor-A that he would consider grading it higher on this aspect under the condition that the tool was applied in the planning phase, in which case the score would be 8.5. on communication, the supervisors gave a score of 7.5, which also shows a positive result, meaning that from their perspective, the tool does improve Communication and coordination in the execution phase. On the other hand, with coordination scored a solid 7.5 in which coordination in which the Supervisor-B scored a 9.

Until now, the supervisors have expressed and positively graded the tool, but the event that demonstrated how much the tool is needed by the stakeholder is the Mistras case. Basically, as part of the communication strategy of the research, a small paper inviting interested stakeholders to get involved in the research project and explaining the basics was conducted. Some days after it was published Somedays, after the article was published, Mistras Group, an international Non-destructive testing and inspections contractor, sent a request asking for the provision of a visualization scene visualizing their scope. As they were contracted for their nondestructive testing (NDT) services, the nature of their scope had particular circumstances that required them to be very location-time driven. NDT services in the oil and gas industry provide nondestructive testing of the different elements like pipelines, tanks, rigs, and a wide variety of different elements.

Complementing this with the Mistras case where a stakeholder external to the research, reached out because of the added value that they saw on the use of the tool. The fact that they were having coordination problems and requested the service of the tool, it says a lot about the tool and is aligned with the comments during the surveys with the contractor where they argued that they believe that contractors would benefit more from the tool than the actual supervisors. For these reasons, it can be said that the tool is appreciated for its added value by the stakeholders.

SQ4: Does the implementation of the visualization tool, on the TAR2019, evidence improvement of labor productivity?

Regarding labor productivity, it can be said that the supervisors, due see how the tool improves labor productivity form the average score they gave the tool of 7.5 in this aspect. However, in the comments for this question, they mention that to grasp on the labor productivity benefits of the tool had to be implemented in the planning phase, and they recurrently mention that the contractors would benefit more from the tool rather than them as BPRR employees. This comments on behalf of the supervisors make sense as it is the contractors the external party who is not familiar with the BPRR refinery, and therefore they are the ones who would benefit the most out of this. The fact that the EVA does not only consider the users of the tool for the TAR2019 as it considers too many factors that do not allow the added value of tool on productivity to be pinpointed on an exact effect on the EVA. For this reason, it can be said that there is no sufficient evidence that the visualization tool improves labor productivity turnarounds, but an important aspect has not been mentioned which is the potential that the tool has on improving productivity. The comments on the feedback on the potential that the tool has was incredible. Moreover, the recurrent comments from the supervisors arguing that it makes more sense to implement the tool on the contractor. Especially as it is the contractor who is burning earned hours in the site, the supervisors are only observing, guiding and controlling. From this sub-question, it is necessary to think about the strategy in which the tool was implemented and evaluated, and how this affected the research results.

MQ: How does the integration of schedule, labor, and geospatial data into a visualization tool provide the means to maximize the labor productivity of an integrated turnaround?

The main question will be answered using the four sub-questions, as stated earlier. To start with, it can be argued that the tool does cover a gap found in the literature which motivated the integration of schedule, labor, and geospatial data based on the answer to sub-question 1. It can also be argued, that the selection of the technology (GIS technologies) and the mean (ArcGIS Pro), in which the tool was designed to provide the turnaround with the tool that covers not only the requirements set by the client but also tackles the gap found in literature, on visualization of labor distribution, was ideal for the intended purpose. One of the findings from this research is incredibly useful and open technology that GIS provides. By open technology, it is meant a technology that is not tied to a specific function but instead lets the user based on his needs and the capabilities of the system build a specific model that covers the functionality he desires. The previous argument can be verified with the answer sub-question 2.

Based on the supervisors' evaluation and reflection on the tool, and the Mistras case, which was an external stakeholder who gained interest in the visualization tool, It can be argued that the tool provided stakeholders with enhanced coordination and communication capabilities. Not only is this enhancement provided, but the tool is also desired in the market as was proven by the Mistras case. The previous findings correspond to the answer on sub-question 3. Regarding the sub-question 4 it has to be concluded that even though there is no sufficient evidence that proves that the visualization tool enhances the labor productivity as the EVA analysis was not conclusive, the visualization tool does have the potential of improving the labor productivity if followed the recommendations given in the coming subchapters.

The double hypothesis proposed can be answered with the results from the previous sub-questions. The initial statement is arguing that; "The integration of schedule, labor, and geospatial data into an open visualization tool will have a positive effect on coordination and communication." will be accepted from the answers of sub-question one, two, and three. The second statement is arguing "visualization tool will improve labor productivity during the execution phase of Integrated turnaround projects," Due to the inconclusive answer from sub-question four, the second hypothesis is annulled. Regardless of this failure to prove the second statement, it is necessary to make the annotation that research found that the potential of improving labor productivity using the visualization tool is very positive and should be further researched.

9.2.Limitations of research

Along with this research, limitations were encountered that restrained the progress of the tool. The first and most importantly if the fact that there are no papers on GIS use on turnaround projects. As there were no papers and no news or any information on the topic, it was tough to find quality data to guide and base the research on. Also, very few articles talked about the use of GIS technologies to visualize labor resources, and the few that did mention it saw this development as something that will come in the future. This has to do with the innovative nature of the research.

Another limitation was that the researcher lacked knowledge in ArcGIS Pro at the start of the research, which means that the learning curve for the first four months, in which the tool was developed for the implementation on TAR2019, was significantly steep. Another limitation to the research was the duration, as there were only 4 months dedicated to designing and developing the tool from scratch to a functional level to be applied int the TAR2019, without having any previous experience on GIS or ArcGIS Pro. Not only did the tool had to be developed during this time, but the stakeholders also had to be involved as well as the literature review had to be developed to back the findings and developments. This required the tool to be implemented in a tremendously accelerated way, which is not ideal for the intended users as the implementation of a new communication sharing technology in an organization require a proper strategy.

Another limitation was the laptop used as all the scenes, macros, and calculations were all done on this computer that did not fit the computational demands in the design process of the tool, and the analysis and update of data. This slowed down the process significantly. Another limitation was the lack of access to the database, as explained in the research, the connection to the database allows interoperability and automation of the tool as well as unlocking specific database query tools that could have speed up the process.

9.3.Recommendation to Company

It is the researchers believe that regardless of not being able to enhance labor productivity, the real added value of this research was introducing the capabilities of these technologies to turnarounds and proving their usefulness. The client has expressed the desire to continue developing these types of technologies to fit their needs. Taking into account that BP already possessed the license for ArcGIS Pro, it would be relatively easy to continue the development of the tool without having to invest significant amounts of money. Given that the first step was taken with this research, BP has an opportunity of developing a genuinely innovative visualization tool that not only has the potential of maximizing productivity but has other applications which have been identified through this research like resource leveling, HSSE application, and activity clash detection that can be replicated in all off their refining plants.

Now, going into the actual recommendations to the company on the further development of this research. Given that the client has three consecutive turnarounds coming up it, the researcher suggests giving immediate continuity to this research hopefully with alongside an educational institution. The first goal to be achieved based on the researcher´s opinion is to achieve interoperability and automation between the data source and the visualization tool. Achieving this would facilitate further applications and researches on the tool. Once this is done, the company can focus on researching the application of the tool in the planning phase for resource-leveling and activity clash detection, the effect of the application of the tool on contractors and HSSE supervisors. Further developments can also be done on the implementation strategy of the tool into the organization and its common processes.

Notice that all the recommendations given to the client have been on the application of turnarounds in order to tackle those organizational complexities characteristic of turnarounds. As said before the application range of the technology is very wide, so the recommendations given to the company would be solely based on the topics covered in the research. In the following subchapter on the recommendation for future researchers recommendations will be given on future researches that might fall off from the focus of this research which is why they are not mentioned in the recommendations to the client, even though they might be interested in applications to be exposed.

9.4.Recommendation to Future researchers

For the recommendations to future researches, a list of future research possibilities will be listed and discussed. As the applications of the technology are so broad, as mentioned before, the recommendations given in this chapter will focus on the oil and gas industry emphasizing on turnarounds with some recommendations on other applications.

Development of the tool for the planning phase of turnarounds to asses activity clash detection to prevent or optimize simultaneous operations. Another development for the planning phase of turnarounds is resource leveling and its applications on front-end loading. Possibilities of integrating BIM within ArcGIS Pro is possible and has been made as was evidenced in the literature review this can have significant application for turnarounds like Activity-Activity, Activity-Physical Element, or Physical Element - Physical Element clash detection. Even though BIM already covers clash detection between physical elements, the added value of GIS technologies would be the simulation of the activity, which is a gap encountered in the literature review on BIM. Future researches can also focus on the implementation of the visualization tool to asses labor hotspots for HSSE applications. Hotspot analysis can also be used for strategic site layout.

The previous recommendations have been on turnarounds but notice that this type of technologies can be used in any maintenance or construction project. It is particularly interesting for turnarounds due to their inherent complex nature, but it can certainly be applied to other type of works. For example, it would be interesting to see the applications of the tool on greenfield project projects were the organization aspect is challenging and the project covers a significant area which are the characteristics that researcher believes that are required to implement the labor visualization tool or any of the other application previously mentioned.

To round up this subchapter, it is crucial to highlight that this research is only a taste of the application and power of GIS technologies pursuing the research applications mentioned will have a positive impact on the challenge to be tackled. It is also very interesting due to the innovative nature of the application of GIS technology as a project management tool in the oil and gas industry. There are definitely developments to be done, and it is a very interesting topic to immerse oneself in.

9.5.Personal Reflection

For the researcher, this study was quite challenging, given the fact that it involved new technologies like GIS and new environments like the oil and gas industry. For this reason, and the fact that the goal was accomplished even though the result were not the expected ones is something to feel proud off, especially under the conditions the research was executed. Another very positive aspect of the research was being able to introduce a technology in a new area of application, in this case, the application GIS technologies on Turnaround management. Thinking back on the first weeks of the research when the design mean of the tool was still being decided, the client proposed to use an open GL program to literally code the whole visualization tool. If GIS technologies had not been discovered, this research would have taken significantly more time or even fall out of the skills of the researcher. It was also curios almost comically to see that even though the client had licensing for ArcGIS, no one knew what the application of the technology was and therefore never thought of relating their problem with it. As was shown through the research, GIS was the perfect technology to tackle the client's needs. For the researcher, it is also interesting to see how every day more and more services within the construction or in this case oil and gas industry are being computerized and automated as the researcher believes that these industries are bit stubborn or antiquated when compared to for example the manufacturing industry. Given all of these reflective points on the research and on the satisfaction of the client the researcher felt proud to lead this investigation and to take the first step in this development which hopefully the client can further develop, implement and replicate on and industry level.

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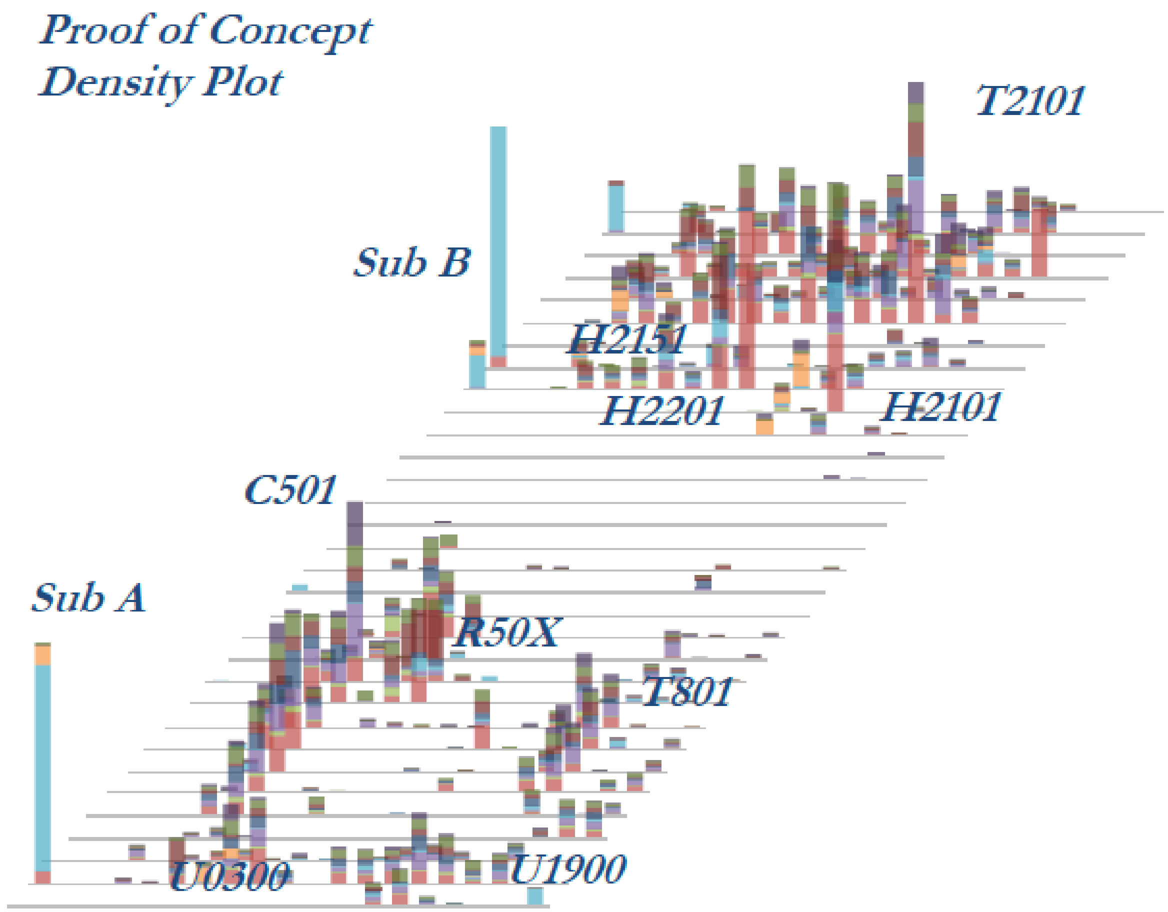
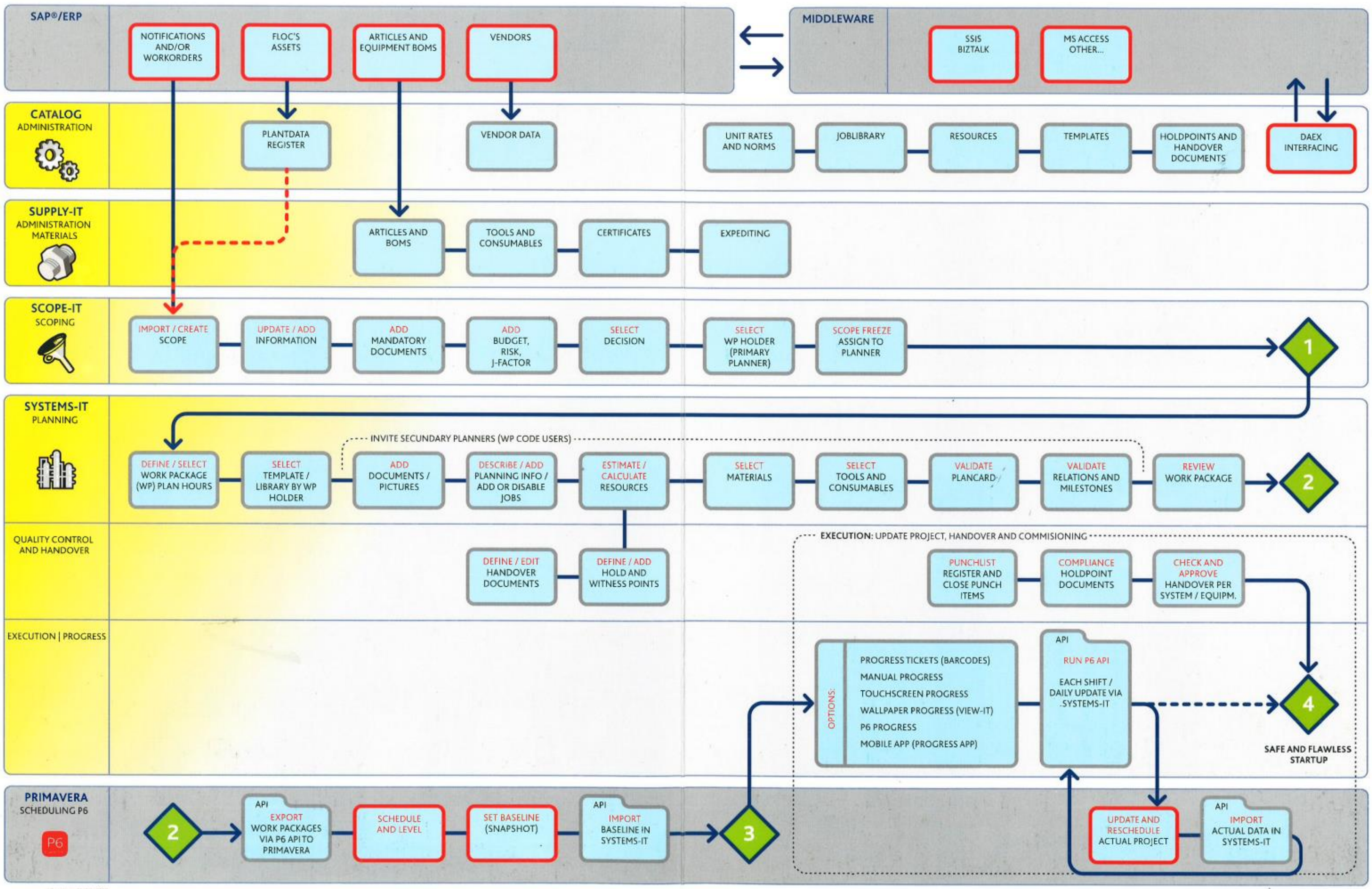
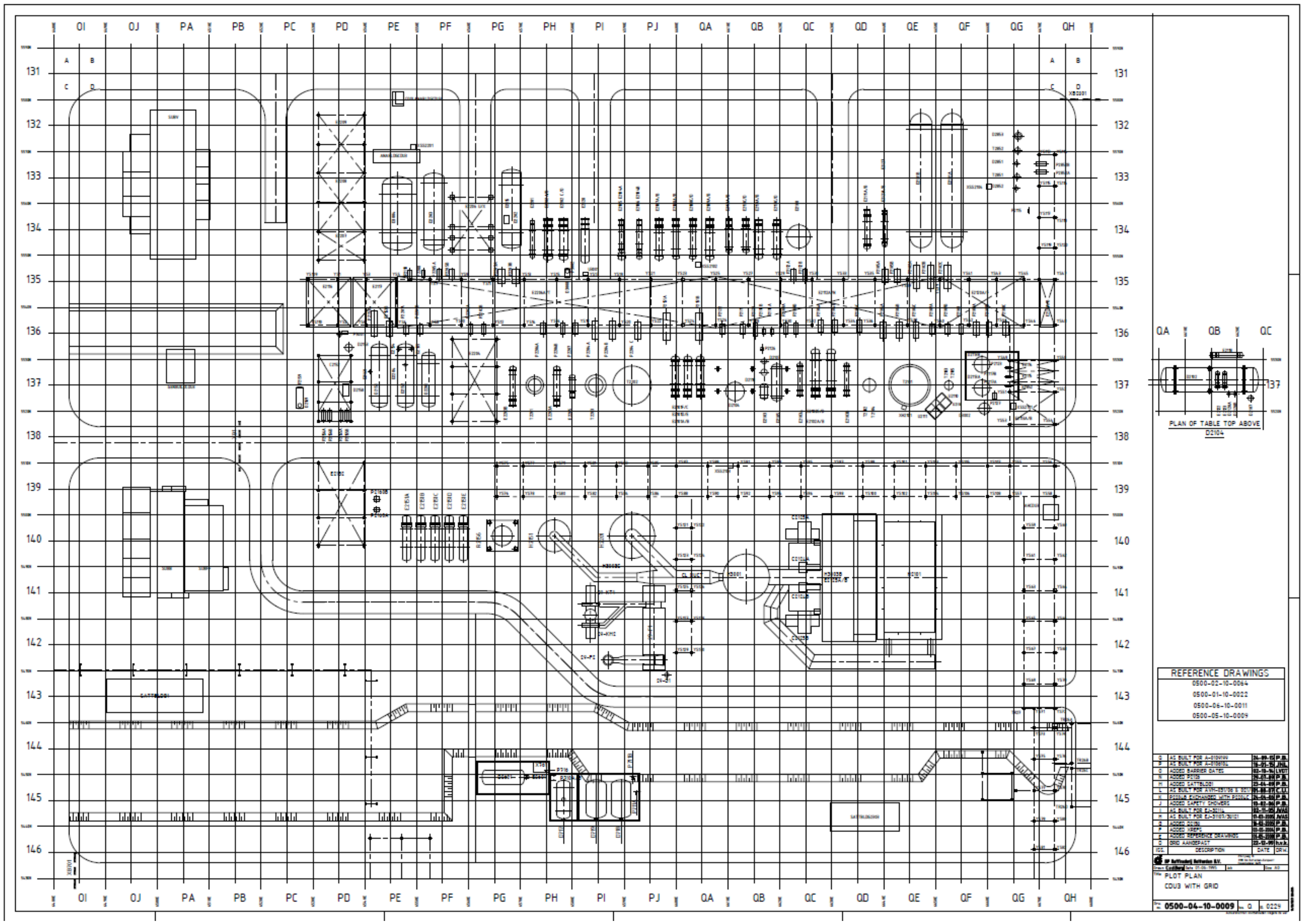
Appendix A: Initial Proof of Concept



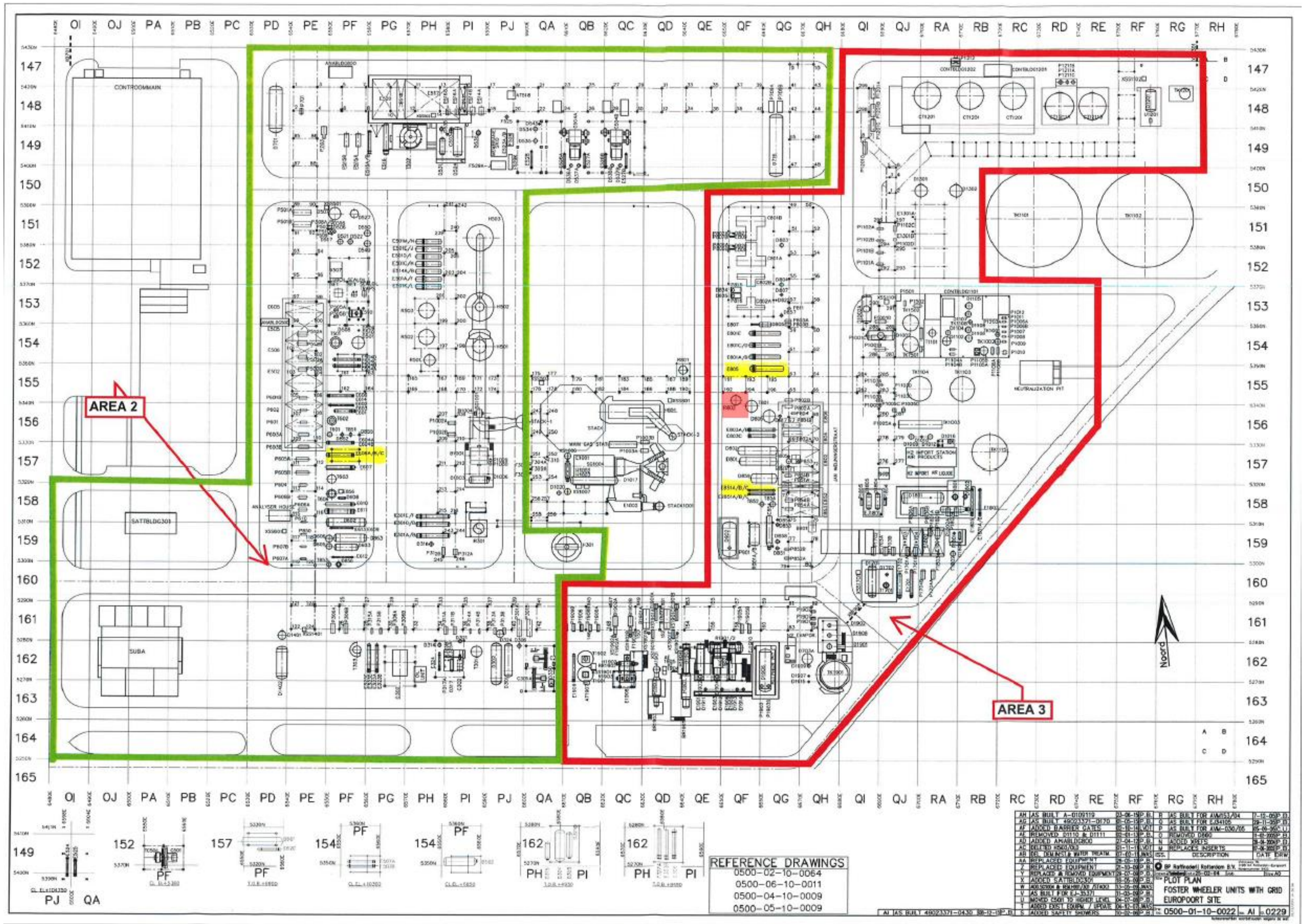
Appendix B: Conceptual Information Workflow for TAR2019



Appendix C: Plot Area-1



Appendix D: Plot Area-2 and 3



Appendix E:Grid system to RD Coordinates

	E	66871.0564	66880.8021	66890.5477	66900.2934	66910.0391	66919.7847	66929.5304	66939.2760	66949.0217	66958.7674	66968.5130	66978.2587	66988.0043	66997.7500	67007.4957	67017.2413	67026.9870	67036.7326	67046.4783	67056.2240	67065.9696	67075.7153	67085.4609	67095.2066	67104.9523	67114.6979
130	N	440243.6758	440241.4348	440239.1938	440236.9528	440234.7118	440232.4707	440230.2297	440227.9887	440225.7477	440223.5067	440221.2657	440219.0247	440216.7837	440214.5427	440212.3017	440210.0607	440207.8197	440205.5787	440203.3377	440201.0967	440198.8556	440196.6146	440194.3736	440192.1326	440189.8916	440187.6506
	E	66868.8154	66878.5611	66888.3067	66898.0524	66907.7981	66917.5437	66927.2894	66937.0350	66946.7807	66956.5264	66966.2720	66976.0177	66985.7633	66995.5090	67005.2547	67015.0003	67024.7460	67034.4916	67044.2373	67053.9830	67063.7286	67073.4743	67083.2199	67092.9656	67102.7113	67112.4569
131	N	440233.9301	440231.6891	440229.4481	440227.2071	440224.9661	440222.7251	440220.4841	440218.2431	440216.0021	440213.7611	440211.5201	440209.2790	440207.0380	440204.7970	440202.5560	440200.3150	440198.0740	440195.8330	440193.5920	440191.3510	440189.1100	440186.8690	440184.6280	440182.3870	440180.1460	440177.9050
	E	66866.5744	66876.3201	66886.0657	66895.8114	66905.5570	66915.3027	66925.0484	66934.7940	66944.5397	66954.2853	66964.0310	66973.7767	66983.5223	66993.2680	67003.0136	67012.7593	67022.5050	67032.2506	67041.9963	67051.7419	67061.4876	67071.2333	67080.9789	67090.7246	67100.4702	67110.2159
132	N	440224.1845	440221.9435	440219.7024	440217.4614	440215.2204	440212.9794	440210.7384	440208.4974	440206.2564	440204.0154	440201.7744	440199.5334	440197.2924	440195.0514	440192.8104	440190.5694	440188.3284	440186.0873	440183.8463	440181.6053	440179.3643	440177.1233	440174.8823	440172.6413	440170.4003	440168.1593
	E	66864.3334	66874.0791	66883.8247	66893.5704	66903.3160	66913.0617	66922.8074	66932.5530	66942.2987	66952.0443	66961.7900	66971.5357	66981.2813	66991.0270	67000.7726	67010.5183	67020.2640	67030.0096	67039.7553	67049.5009	67059.2466	67068.9923	67078.7379	67088.4836	67098.2292	67107.9749
133	N	440214.4388	440212.1978	440209.9568	440207.7158	440205.4748	440203.2338	440200.9928	440198.7518	440196.5107	440194.2697	440192.0287	440189.7877	440187.5467	440185.3057	440183.0647	440180.8237	440178.5827	440176.3417	440174.1007	440171.8597	440169.6187	440167.3777	440165.1367	440162.8956	440160.6546	440158.4136
	E	66862.0924	66871.8381	66881.5837	66891.3294	66901.0750	66910.8207	66920.5664	66930.3120	66940.0577	66949.8033	66959.5490	66969.2947	66979.0403	66988.7860	66998.5316	67008.2773	67018.0230	67027.7686	67037.5143	67047.2599	67057.0056	67066.7513	67076.4969	67086.2426	67095.9882	67105.7339
134	N	440204.6931	440202.4521	440200.2111	440197.9701	440195.7291	440193.4881	440191.2471	440189.0061	440186.7651	440184.5241	440182.2831	440180.0421	440177.8011	440175.5601	440173.3190	440171.0780	440168.8370	440166.5960	440164.3550	440162.1140	440159.8730	440157.6320	440155.3910	440153.1500	440150.9090	440148.6680
	E	66859.8514	66869.5970	66879.3427	66889.0884	66898.8340	66908.5797	66918.3253	66928.0710	66937.8167	66947.5623	66957.3080	66967.0536	66976.7993	66986.5450	66996.2906	67006.0363	67015.7819	67025.5276	67035.2733	67045.0189	67054.7646	67064.5102	67074.2559	67084.0016	67093.7472	67103.4929
135	N	440194.9475	440192.7065	440190.4655	440188.2245	440185.9835	440183.7424	440181.5014	440179.2604	440177.0194	440174.7784	440172.5374	440170.2964	440168.0554	440165.8144	440163.5734	440161.3324	440159.0914	440156.8504	440154.6094	440152.3684	440150.1273	440147.8863	440145.6453	440143.4043	440141.1633	440138.9223
	E	66857.6104	66867.3560	66877.1017	66886.8474	66896.5930	66906.3387	66916.0843	66925.8300	66935.5757	66945.3213	66955.0670	66964.8126	66974.5583	66984.3040	66994.0496	67003.7953	67013.5409	67023.2866	67033.0323	67042.7779	67052.5236	67062.2692	67072.0149	67081.7606	67091.5062	67101.2519
136	N	440185.2018	440182.9608	440180.7198	440178.4788	440176.2378	440173.9968	440171.7558	440169.5148	440167.2738	440165.0328	440162.7918	440160.5507	440158.3097	440156.0687	440153.8277	440151.5867	440149.3457	440147.1047	440144.8637	440142.6227	440140.3817	440138.1407	440135.8997	440133.6587	440131.4177	440129.1767
	E	66855.3694	66865.1150	66874.8607	66884.6064	66894.3520	66904.0977	66913.8433	66923.5890	66933.3347	66943.0803	66952.8260	66962.5716	66972.3173	66982.0630	66991.8086	67001.5543	67011.2999	67021.0456	67030.7913	67040.5369	67050.2826	67060.0282	67069.7739	67079.5196	67089.2652	67099.0109
137	N	440175.4562	440173.2152	440170.9741	440168.7331	440166.4921	440164.2511	440162.0101	440159.7691	440157.5281	440155.2871	440153.0461	440150.8051	440148.5641	440146.3231	440144.0821	440141.8411	440139.6001	440137.3590	440135.1180	440132.8770	440130.6360	440128.3950	440126.1540	440123.9130	440121.6720	440119.4310
	E	66853.1284	66862.8740	66872.6197	66882.3653	66892.1110	66901.8567	66911.6023	66921.3480	66931.0936	66940.8393	66950.5850	66960.3306	66970.0763	66979.8219	66989.5676	66999.3133	67009.0589	67018.8046	67028.5502	67038.2959	67048.0416	67057.7872	67067.5329	67077.2785	67087.0242	67096.7699
138	N	440165.7105	440163.4695	440161.2285	440158.9875	440156.7465	440154.5055	440152.2645	440150.0235	440147.7824	440145.5414	440143.3004	440141.0594	440138.8184	440136.5774	440134.3364	440132.0954	440129.8544	440127.6134	440125.3724	440123.1314	440120.8904	440118.6494	440116.4084	440114.1673	440111.9263	440109.6853
	E	66850.8874	66860.6330	66870.3787	66880.1243	66889.8700	66899.6157	66909.3613	66919.1070	66928.8526	66938.5983	66948.3440	66958.0896	66967.8353	66977.5809	66987.3266	66997.0723	67006.8179	67016.5636	67026.3092	67036.0549	67045.8006	67055.5462	67065.2919	67075.0375	67084.7832	67094.5289
139	N	440155.9648	440153.7238	440151.4828	440149.2418	440147.0008	440144.7598	440142.5188	440140.2778	440138.0368	440135.7958	440133.5548	440131.3138	440129.0728	440126.8318	440124.5907	440122.3497	440120.1087	440117.8677	440115.6267	440113.3857	440111.1447	440108.9037	440106.6627	440104.4217	440102.1807	440099.9397
	E	66848.6464	66858.3920	66868.1377	66877.8833	66887.6290	66897.3747	66907.1203	66916.8660	66926.6116	66936.3573	66946.1030	66955.8486	66965.5943	66975.3399	66985.0856	66994.8313	67004.5769	67014.3226	67024.0682	67033.8139	67043.5596	67053.3052	67063.0509	67072.7965	67082.5422	67092.2879
140	N	440146.2192	440143.9782	440141.7372	440139.4962	440137.2552	440135.0141	440132.7731	440130.5321	440128.2911	440126.0501	440123.8091	440121.5681	440119.3271	440117.0861	440114.8451	440112.6041	440110.3631	440108.1221	440105.8811	440103.6401	440101.3990	440099.1580	440096.9170	440094.6760	440092.4350	440090.1940
	E	66846.4053	66856.1510	66865.8967	66875.6423	66885.3880	66895.1336	66904.8793	66914.6250	66924.3706	66934.1163	66943.8619	66953.6076	66963.3533	66973.0989	66982.8446	66992.5902	67002.3359	67012.0816	67021.8272	67031.5729	67041.3185	67051.0642	67060.8099	67070.5555	67080.3012	67090.0468
141	N	440136.4735	440134.2325	440131.9915	440129.7505	440127.5095	440125.2685	440123.0275	440120.7865	440118.5455	440116.3045	440114.0635	440111.8224	440109.5814	440107.3404	440105.0994	440102.8584	440100.6174	440098.3764	440096.1354	440093.8944	440091.6534	440089.4124	440087.1714	440084.9304	440082.6894	440080.4484
	E	66844.1643	66853.9100	66863.6557	66873.4013	66883.1470	66892.8926	66902.6383	66912.3840	66922.1296	66931.8753	66941.6209	66951.3666	66961.1123	66970.8579	66980.6036	66990.3492	67000.0949	67009.8406	67019.5862	67029.3319	67039.0775	67048.8232	67058.5689	67068.3145	67078.0602	67087.8058
142	N	440126.7279	440124.4869	440122.2458	440120.0048	440117.7638	440115.5228	440113.2818	440111.0408	440108.7998	440106.5588	440104.3178	440102.0768	440099.8358	440097.5948	440095.3538	440093.1128	440090.8718	440088.6307	440086.3897	440084.1487	440081.9077	440079.6667	440077.4257	440075.1847	440072.9437	440070.7027
	E	66841.9233	66851.6690	66861.4147	66871.1603	66880.9060	66890.6516	66900.3973	66910.1430	66919.8886	66929.6343	66939.3799	66949.1256	66958.8713	66968.6169	66978.3626	66988.1082	66997.8539	67007.5996	67017.3452	67027.0909	67036.8365	67046.5822	67056.3279	67066.0735	67075.8192	67085.5648
143	N	440116.9822	440114.7412	440112.5002	440110.2592	440108.0182	440105.7772	440103.5362	440101.2952	440099.0541	440096.8131	440094.5721	440092.3311	440090.0901	440087.8491	440085.6081	440083.3671	440081.1261	440078.8851	440076.6441	440074.4031	440072.1621	440069.9211	440067.6801	440065.4390	440063.1980	440060.9570
	E	66839.6823	66849.4280	66859.1736	66868.9193	66878.6650	66888.4106	66898.1563	66907.9019	66917.6476	66927.3933	66937.1389	66946.8846	66956.6302	66966.3759	66976.1216	66985.8672	66995.6129	67005.3585	67015.1042	67024.8499	67034.5955	67044.3412	67054.0868	67063.8325	67073.5782	67083.3238
144	N	440107.2365	440104.9955	440102.7545	440100.5135	440098.2725	440096.0315	440093.7905	440091.5495	440089.3085	440087.0675	440084.8265	440082.5855	440080.3445	440078.1035	440075.8624	440073.6214	440071.3804	440069.1394	440066.8984	440064.6574	440062.4164	440060.1754	440057.9344	440055.6934	440053.4524	440051.2114
	E	66837.4413	66847.1870	66856.9326	66866.6783	66876.4240	66886.1696	66895.9153	66905.6609	66915.4066	66925.1523	66934.8979	66944.6436	66954.3892	66964.1349	66973.8806	66983.6262	66993.3719	67003.1175	67012.8632	67022.6089	67032.3545	67042.1002	67051.8458	67061.5915	67071.3372	67081.0828
145	N	440097.4909	440095.2499	440093.0089	440090.7679	440088.5269	440086.2858	440084.0448	440081.8038	440079.5628	440077.3218	440075.0808	440072.8398	440070.5988	440068.3578	440066.1168	440063.8758	440061.6348	440059.3938	440057.1528	440054.9118	440052.6707	440050.4297	440048.1887	440045.9477	440043.7067	440041.4657
	E	66835.2003	66844.9460	66854.6916	66864.4373	66874.1830	66883.9286	66893.6743	66903.4199	66913.1656	66922.9113	66932.6569	66942.4026	66952.1482	66961.8939	66971.6396	66981.3852	66991.1309	67000.8765	67010.6222	67020.3679	67030.1135	67039.8592	67049.6048	67059.3505	67069.0962	67078.8418
146	N	440087.7452	440085.5042	440083.2632	440081.0222	440078.7812	440076.5402	440074.2992	440072.0582	440069.8172	440067.5762	440065.3352	440063.0941	440060.8531	440058.6121	440056.3711	440054.1301	440051.8891	440049.6481	440047.4071	440045.1661	440042.9251	440040.6841	440038.4431	440036.2021	440033.9611	440031.7201
	E	66832.9593	66842.7050	66852.4506	66862.1963	66871.9419	66881.6876	66891.4333	66901.1789	66910.9246	66920.6702	66930.4159	66940.1616	66949.9072	66959.6529	66969.3985	66979.1442	66988.8899	66998.6355	67008.3812	67018.1268	67027.8725	67037.6182	67047.3638	67057.1095	67066.8551	67076.6008
147	N	440077.9996	440075.7586	440073.5175	440071.2765	440069.0355	440066.7945	440064.5535	440062.3125	440060.0715	440057.8305	440055.5895	440053.3485	440051.1075	440048.8665	440046.6255	440044.3845	440042.1435	440039.9024	440037.6614	440035.4204	440033.1794	440030.9384	440028.6974	440026.4564	440024.2154	440021.9744
	E	66830.7183	66840.4640	66850.2096	66859.9553	66869.7009	66879.4466	66889.1923	66898.9379	66908.6836	66918.4292	66928.1749	66937.9206	66947.6662	66957.4119	66967.1575	66976.9032	66986.6489	66996.3945	67006.1402	67015.8858	67025.6315	67035.3772	67045.1228	67054.8685	67064.6141	67074.3598
148	N	440068.2539	440066.0129	440063.7719	440061.5309	440059.2899	440057.0489	440054.8079	440052.5669	440050.3258	440048.0848	440045.8438	440043.6028	440041.3618	440039.1208	440036.8798	440034.6388	440032.3978	440030.1568	440027.9158	440025.6748	440023.4338	440021.1928	440018.9518	440016.7107	440014.4697	440012.2287
	E	66828.4773	66838.2230	66847.9686	66857.7143	66867.4599	66877.2056	66886.9513	66896.6969	66906.4426	66916.1882	66925.9339	66935.6796	66945.4252	66955.1709	66964.9165	66974.6622	66984.4079	66994.1535	67003.8992	67013.6448	67023.3905	67033.1362	67042.8818	67052.6275	67062.3731	67072.1188
149	N	440058.5082	440056.2672	440054.0262	440051.7852	440049.5442	440047.3032	440045.0622	440042.8212	440040.5802	440038.3392	440036.0982	440033.8572	440031.6162	440029.3752	440027.1341	440024.8931	440022.6521	440020.4111	440018.1701	440015.9291	440013.6881	440011.4471	440009.2061	440006.9651	440004.7241	440002.4831
	E	66826.2363	66835.9819	66845.7276	66855.4733	66865.2189	66874.9646	66884.7102	66894.4559	66904.2016	66913.9472	66923.6929	66933.4385	66943.1842	66952.9299	66962.6755	66972.4212	66982.1668	66991.9125	67001.6582	67011.4038	67021.1495	67030.8951	67040.6408	67050.3865	67060.1321	67069.8778
150	N	440048.7626	440046.5216	440044.2806	440042.0396	440039.7986	440037.5575	440035.3165	440033.0755	440030.8345	440028.5935	440026.3525	440024.1115	440021.8705	440019.6295	440017.3885	440015.1475	440012.9065	440010.6655	440008.4245	440006.1835	440003.9424	440001.7014	439999.4604	439997.2194	439994.9784	439992.7374
	E	66823.9953	66833.7409	66843.4866	66853.2323	66862.9779	66872.7236	66882.4692	66892.2149	66901.9606	66911.7062	66921.4519	66931.1975	66940.9432	66950.6889	66960.4345	66970.1802	66979.9258	66989.6715	66999.4172	67009.1628	67018.9085	67028.6541	67038.3998	67048.1455	67057.8911	67067.6368
151	N	440039.0169	440036.7759	440034.5349	440032.2939	440030.0529	440027.8119	440025.5709	440023.3299	440021.0889	440018.8479	440016.6069	440014.3658	440012.1248	440009.8838	440007.6428	440005.4018	440003.1608	440000.9198	439998.6788	439996.4378	439994.1968	439991.9558	439989.7148	439987.4738	439985.2328	439982.9918
	E	66821.7543	66831.4999	66841.2456	66850.9913	66860.7369	66870.4826	66880.2282	66889.9739	66899.7196	66909.4652	66919.2109	66928.9565	66938.7022	66948.4479	66958.1935	66967.9392	66977.6848	66987.4305	66997.1762	67006.9218	67016.6675	67026.4131	67036.1588	67045.9045	67055.6501	67065.3958
152	N	440029.2713	440027.0303	440024.7892	440022.5482	440020.3072	440018.0662	440015.8252	440013.5842	440011.3432	440009.1022	440006.8612	440004.6202	440002.3792	440000.1382	439997.8972	439995.6562	439993.4152	439991.1741	439988.9331	439986.6921	439984.4511	439982.2101	439979.9691	439977.7281	439975.4871	439973.2461
	E	66819.5133	66829.2589	66839.0046	66848.7502	66858.4959	66868.2416	66877.9872	66887.7329	66897.4785	66907.2242	66916.9699	66926.7155	66936.4612	66946.2068	66955.9525	66965.6982	66975.4438	66985.1895	66994.9351	67004.6808	67014.4265	67024.1721	67033.9178	67043.6634	67053.4091	67063.1548
153	N	440019.5256	440017.2846	440015.0436	440012.8026	440010.5616	440008.3206	440006.0796	440003.8386	440001.5975	439999.3565	439997.1155	439994.8745	439992.6335	439990.3925	439988.1515	439985.9105	439983.6695	439981.4285	439979.1875	439976.9465	439974.7055	439972.4645	439970.2235	439967.9824	439965.7414	439963.5004
	E	66817.2723	66827.0179	66836.7636	66846.5092	66856.2549	66866.0006	66875.7462	66885.4919	66895.2375	66904.9832	66914.7289	66924.4745	66934.2202	66943.9658	66953.7115	66963.4572	66973.2028	66982.9485	66992.6941	67002.4398	67012.1855	67021.9311	67031.6768	67041.4224	67051.1681	67060.9138
154	N	440009.7799	440007.5389	440005.2979	440003.0569	440000.8159	439998.5749	439996.3339	439994.0929	439991.8519	439989.6109	439987.3699	439985.1289	439982.8879	439980.6469	439978.4058	439976.1648	439973.9238	439971.6828	439969.4418	439967.2008	439964.9598	439962.7188	439960.4778	439958.2368	439955.9958	439953.7548
	E	66815.0313	66824.7769	66834.5226	66844.2682	66854.0139	66863.7596	66873.5052	66883.2509	66892.9965	66902.7422	66912.4879	66922.2335	66931.9792	66941.7248	66951.4705	66961.2162	66970.9618	66980.7075	66990.4531	67000.1988	67009.9445	67019.6901	67029.4358	67039.1814	67048.9271	67058.6728
155	N	440000.0343	439997.7933	439995.5523	439993.3113	439991.0703	439988.8292	439986.5882	439984.3472	439982.1062	439979.8652	439977.6242	439975.3832	439973.1422	439970.9012	439968.6602	439966.4192	439964.1782	439961.9372	439959.6962	439957.4552	439955.2141	439952.9731	439950.7321	439948.4911	439946.2501	439944.0091
	E	66812.7902	66822.5359	66832.2816	66842.0272	66851.7729	66861.5185	66871.2642	66881.0099	66890.7555	66900.5012	66910.2468	66919.9925	66929.7382	66939.4838	66949.2295	66958.9751	66968.7208	66978.4665	66988.2121	66997.9578	67007.7034	67017.4491	67027.1948	67036.9404	67046.6861	67056.4317
156	N	439990.2886	439988.0476	439985.8066	439983.5656	439981.3246	439979.0836	439976.8426	439974.6016	439972.3606	439970.1196	439967.8786	439965.6375	439963.3965	439961.1555	439958.9145	439956.6735	439954.4325	439952.1915	439949.9505	439947.7095	439945.4685	439943.2275	439940.9865	439938.7455	439936.5045	439934.2635
	E	66810.5492	66820.2949	66830.0406	66839.7862	66849.5319	66859.2775	66869.0232	66878.7689	66888.5145	66898.2602	66908.0058	66917.7515	66927.4972	66937.2428	66946.9885	66956.7341	66966.4798	66976.2255	66985.9711	66995.7168	67005.4624	67015.2081	67024.9538	67034.6994	67044.4451	67054.1907
157	N	439980.5430	439978.3020	439976.0609	439973.8199	439971.5789	439969.3379	439967.0969	439964.8559	439962.6149	439960.3739	439958.1329	439955.8919	439953.6509	439951.4099	439949.1689	439946.9279	439944.6869	439942.4458	439940.2048	439937.9638	439935.7228	439933.4818	439931.2408	439928.9998	439926.7588	439924.5178
	E	66808.3082	66818.0539	66827.7996	66837.5452	66847.2909	66857.0365	66866.7822	66876.5279	66886.2735	66896.0192	66905.7648	66915.5105	66925.2562	66935.0018	66944.7475	66954.4931	66964.2388	66973.9845	66983.7301	66993.4758	67003.2214	67012.9671	67022.7128	67032.4584	67042.2041	67051.9497
158	N	439970.7973	439968.5563	439966.3153	439964.0743	439961.8333	439959.5923	439957.3513	439955.1103	439952.8692	439950.6282	439948.3872	439946.1462	439943.9052	439941.6642	439939.4232	439937.1822	439934.9412	439932.7002	439930.4592	439928.2182	439925.9772	439923.7362	439921.4952	439919.2541	439917.0131	439914.7721
	E	66806.0672	66815.8129	66825.5585	66835.3042	66845.0499	66854.7955	66864.5412	66874.2868	66884.0325	66893.7782	66903.5238	66913.2695	66923.0151	66932.7608	66942.5065	66952.2521	66961.9978	66971.7434	66981.4891	66991.2348	67000.9804	67010.7261	67020.4717	67030.2174	67039.9631	67049.7087
159	N	439961.0516	439958.8106	439956.5696	439954.3286	439952.0876	439949.8466	439947.6056	439945.3646	439943.1236	439940.8826	439938.6416	439936.4006	439934.1596	439931.9186	439929.6775	439927.4365	439925.1955	439922.9545	439920.7135	439918.4725	439916.2315	439913.9905	439911.7495	439909.5085	439907.2675	439905.0265
	E	66803.8262	66813.5719	66823.3175	66833.0632	66842.8089	66852.5545	66862.3002	66872.0458	66881.7915	66891.5372	66901.2828	66911.0285	66920.7741	66930.5198	66940.2655	66950.0111	66959.7568	66969.5024	66979.2481	66988.9938	66998.7394	67008.4851	67018.2307	67027.9764	67037.7221	67047.4677
160	N	439951.3060	439949.0650	439946.8240	439944.5830	439942.3420	439940.1009	439937.8599	439935.6189	439933.3779	439931.1369	439928.8959	439926.6549	439924.4139	439922.1729	439919.9319	439917.6909	439915.4499	439913.2089	439910.9679	439908.7269	439906.4858	439904.2448	439902.0038	439899.7628	439897.5218	439895.2808
	E	66801.5852	66811.3309	66821.0765	66830.8222	66840.5679	66850.3135	66860.0592	66869.8048	66879.5505	66889.2962	66899.0418	66908.7875	66918.5331	66928.2788	66938.0245	66947.7701	66957.5158	66967.2614	66977.0071	66986.7528	66996.4984	67006.2441	67015.9897	67025.7354	67035.4811	67045.2267
161	N	439941.5603	439939.3193	439937.0783	439934.8373	439932.5963	439930.3553	439928.1143	439925.8733	439923.6323	439921.3913	439919.1503	439916.9092	439914.6682	439912.4272	439910.1862	439907.9452	439905.7042	439903.4632	439901.2222	439898.9812	439896.7402	439894.4992	439892.2582	439890.0172	439887.7762	439885.5352
	E	66799.3442	66809.0899	66818.8355	66828.5812	66838.3268	66848.0725	66857.8182	66867.5638	66877.3095	66887.0551	66896.8008	66906.5465	66916.2921	66926.0378	66935.7834	66945.5291	66955.2748	66965.0204	66974.7661	66984.5117	66994.2574	67004.0031	67013.7487	67023.4944	67033.2400	67042.9857
162	N	439931.8147	439929.5737	439927.3326	439925.0916	439922.8506	439920.6096	439918.3686	439916.1276	439913.8866	439911.6456	439909.4046	439907.1636	439904.9226	439902.6816	439900.4406	439898.1996	439895.9586	439893.7175	439891.4765	439889.2355	439886.9945	439884.7535	439882.5125	439880.2715	439878.0305	439875.7895
	E	66797.1032	66806.8489	66816.5945	66826.3402	66836.0858	66845.8315	66855.5772	66865.3228	66875.0685	66884.8141	66894.5598	66904.3055	66914.0511	66923.7968	66933.5424	66943.2881	66953.0338	66962.7794	66972.5251	66982.2707	66992.0164	67001.7621	67011.5077	67021.2534	67030.9990	67040.7447
163	N	439922.0690	439919.8280	439917.5870	439915.3460	439913.1050	439910.8640	439908.6230	439906.3820	439904.1409	439901.8999	439899.6589	439897.4179	439895.1769	439892.9359	439890.6949	439888.4539	439886.2129	439883.9719	439881.7309	439879.4899	439877.2489	439875.0079	439872.7669	439870.5258	439868.2848	439866.0438
		OI	OJ	PA	PB	PC	PD	PE	PF	PG	PH	PI	PJ	QA	QB	QC	QD	QE	QF	QG	QH	QI	QJ	RA	RB	RC	RD

Appendix F: Color Code Diagram

Color order: Rainbow Convenient **Color code:** Hex RGB CMYK **Accessibility:** 95% 99% 99.99% 100%

Maroon #800000	Brown #9A6324	Olive #808000			Teal #469990	Navy #000075			Black #000000
Red #e6194B	Orange #f58231	Yellow #ffe119	Lime #bfef45	Green #3cb44b	Cyan #42d4f4	Blue #4363d8	Purple #911eb4	Magenta #f032e6	Grey #a9a9a9
Pink #fabebe	Apricot #ffd8b1	Beige #fffac8		Mint #aaffc3			Lavender #e6beff		White #ffffff

```
#e6194B, #3cb44b, #ffe119, #4363d8, #f58231, #911eb4, #42d4f4, #f032e6, #bfef45, #fabebe, #469990, #e6beff, #9A6324, #fffac8, #800000, #aaffc3,
#808000, #ffd8b1, #000075, #a9a9a9, #ffffff, #000000
```

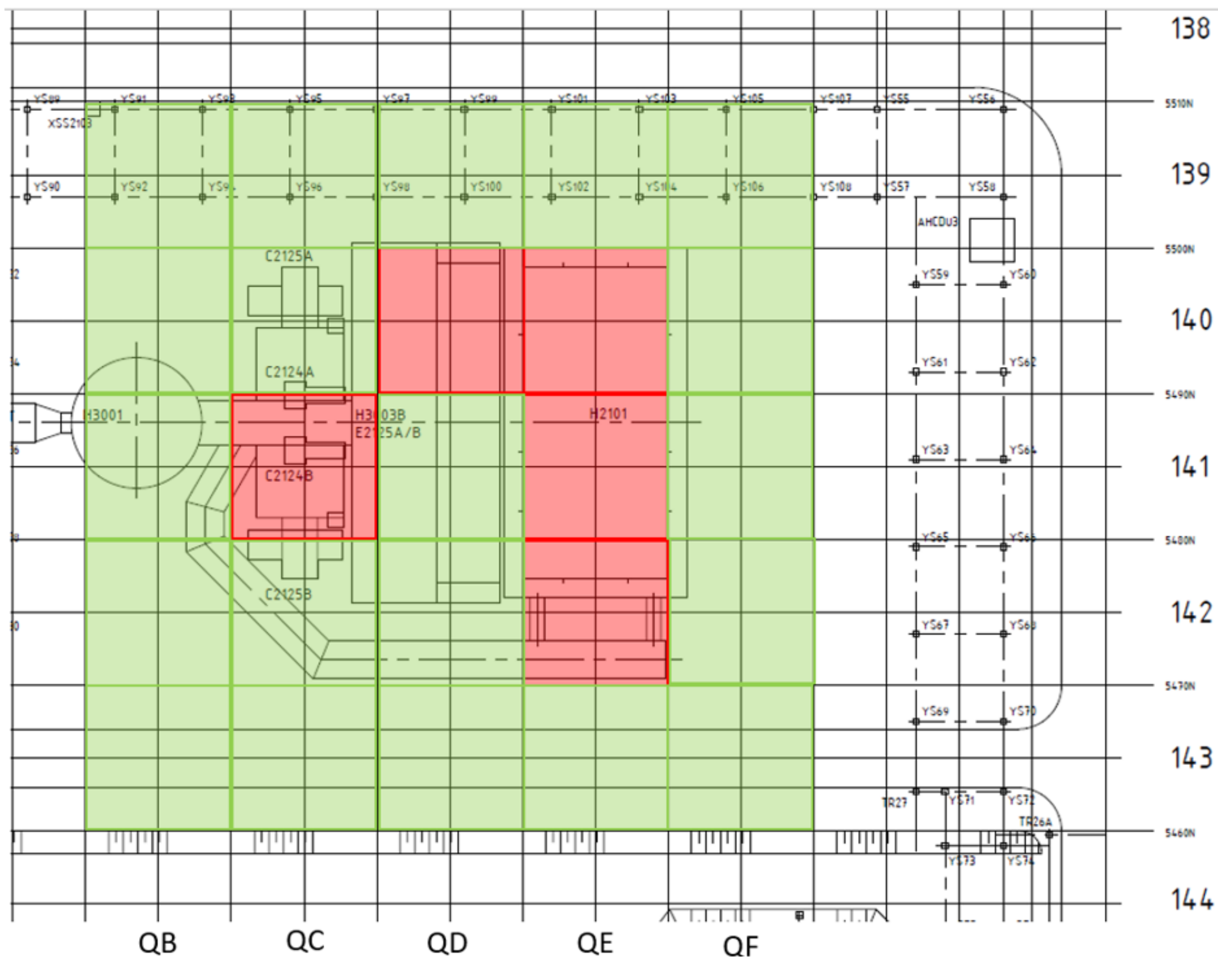
Appendix G: Data Set Example

SCOPE NO.	JOB	SCOPECODE	EWR	RESOURCE	CONTRACTOR	TOTAL HOURS	BPS	BPF	PS	PF	AS	AF	PROGRESS	WBS	OBS	GRID ALPH	GRID NUM	Discipline
2019845	056 - FINAL RELEASE ASSEMBLE AND CLOSING EQUIPMENT	EOL - END OF LIFE	FALSE	AKI	BP	1	28/05/2019	28/05/2019	13/06/2019	13/06/2019	13/06/2019	0/01/1900	0	1.1 - AREA_1	1.53 - Wassenaar, Marco van	QA	135	1 - TAR Support
2019846	054 - FINAL RELEASE ASSEMBLE AND CLOSING EQUIPMENT	EOL - END OF LIFE	FALSE	AKI	BP	1	29/05/2019	29/05/2019	13/06/2019	13/06/2019	13/06/2019	0/01/1900	0	1.1 - AREA_1	1.53 - Wassenaar, Marco van	QA	135	1 - TAR Support
2019847	054 - FINAL RELEASE ASSEMBLE AND CLOSING EQUIPMENT	EOL - END OF LIFE	FALSE	AKI	BP	1	30/05/2019	30/05/2019	13/06/2019	13/06/2019	13/06/2019	0/01/1900	0	1.1 - AREA_1	1.53 - Wassenaar, Marco van	QB	135	1 - TAR Support
2020153	014 - SODA ASH WASH AND CLEANING (INCLUDING NEUTRALIZATION AND DRY PERIOD)	ADD - ADDITIONAL SCOPE MAINTENANCE	FALSE	CL_HD	BUCHEN CLEANING AREA-1	6	16/05/2019	17/05/2019	25/05/2019	25/05/2019	25/05/2019	25/05/2019	1	1.1 - AREA_1	1.53 - Wassenaar, Marco van	QA	136	5 - Cleaning & Cat
2020153	014 - SODA ASH WASH AND CLEANING (INCLUDING NEUTRALIZATION AND DRY PERIOD)	ADD - ADDITIONAL SCOPE MAINTENANCE	FALSE	CL_VAC	BUCHEN CLEANING AREA-1	6	16/05/2019	17/05/2019	25/05/2019	25/05/2019	25/05/2019	25/05/2019	1	1.1 - AREA_1	1.53 - Wassenaar, Marco van	QA	136	5 - Cleaning & Cat
2020153	016 - REMOVE TEMPORARY CONNECTIONS OPERATIONS	ADD - ADDITIONAL SCOPE MAINTENANCE	FALSE	CR035	PEINEMANN	4	20/05/2019	25/05/2019	21/05/2019	27/05/2019	20/05/2019	0/01/1900	0.75	1.1 - AREA_1	1.53 - Wassenaar, Marco van	QA	136	1 - TAR Support
2018041	045 - EXTERNAL INSPECTION EQUIPMENT	BSC - BASIC TAR SCOPE MAINTENANCE	FALSE	AKI	BP	1	30/05/2019	30/05/2019	30/05/2019	30/05/2019	29/05/2019	29/05/2019	1	1.2 - AREA_2	1.16 - Goeij, Martin de	PJ	162	1 - TAR Support
2018041	046 - INTERNAL INSPECTION EQUIPMENT	BSC - BASIC TAR SCOPE MAINTENANCE	FALSE	AKI	BP	1	30/05/2019	31/05/2019	30/05/2019	31/05/2019	29/05/2019	29/05/2019	1	1.2 - AREA_2	1.16 - Goeij, Martin de	PJ	162	1 - TAR Support
2018040	045 - EXTERNAL INSPECTION EQUIPMENT	BSC - BASIC TAR SCOPE MAINTENANCE	FALSE	AKI	BP	1	27/05/2019	27/05/2019	31/05/2019	31/05/2019	31/05/2019	31/05/2019	1	1.2 - AREA_2	1.16 - Goeij, Martin de	PI	162	1 - TAR Support
2020209	003 - DISCONNECT INSTRUMENTATION	EWR - EXTRA WORK MAINTENANCE	TRUE	TAEC	SPIE E/I AREA-1	3	0/01/1900	0/01/1900	31/05/2019	31/05/2019	27/05/2019	27/05/2019	1	1.1 - AREA_1	1.27 - Konijnenburg, John	PH	137	7 - Elec & Instr
2020209	004 - CONNECT INSTRUMENTS	EWR - EXTRA WORK MAINTENANCE	TRUE	TAEC	SPIE E/I AREA-1	6	0/01/1900	0/01/1900	15/06/2019	17/06/2019	15/06/2019	15/06/2019	1	1.1 - AREA_1	1.27 - Konijnenburg, John	PH	137	7 - Elec & Instr
2020209	005 - TEST, COMMISSION & PUNCH INSTRUMENTS (QC FINAL)	EWR - EXTRA WORK MAINTENANCE	TRUE	TAEC	SPIE E/I AREA-1	4.37	0/01/1900	0/01/1900	18/06/2019	18/06/2019	0/01/1900	0/01/1900		1.1 - AREA_1	1.27 - Konijnenburg, John	PH	137	7 - Elec & Instr
2019993	009 - FINAL APPROVAL ITP	MICRO - PROJECT MICRO	FALSE	IMPID	BP	2	14/05/2019	14/05/2019	25/06/2019	25/06/2019	0/01/1900	0/01/1900		1.3 - AREA_3	1.2 - Ricky Avinash	QF	155	1 - TAR Support
2019993	011 - VVI INSPECTION ITP	MICRO - PROJECT MICRO	FALSE	IMPID	BP	2	10/06/2019	10/06/2019	26/06/2019	26/06/2019	0/01/1900	0/01/1900		1.3 - AREA_3	1.2 - Ricky Avinash	QF	155	1 - TAR Support
2019993	009 - FINAL APPROVAL ITP	MICRO - PROJECT MICRO	FALSE	INSP	BP	1	14/05/2019	14/05/2019	25/06/2019	25/06/2019	0/01/1900	0/01/1900		1.3 - AREA_3	1.2 - Ricky Avinash	QF	155	1 - TAR Support
2022262	077 - FINISH ITP BY PID BEFORE TESTING	MICRO EWR - EWR SCOPE PROJECT PORT-FOLIO	TRUE	IMPID	BP	1	0/01/1900	0/01/1900	21/06/2019	21/06/2019	0/01/1900	0/01/1900		1.3 - AREA_3	1.2 - Ricky Avinash	QG	156	1 - TAR Support
2022262	079 - INSPECTION HYDROSTATIC TESTING PIPING	MICRO EWR - EWR SCOPE PROJECT PORT-FOLIO	TRUE	IMPID	BP	1	0/01/1900	0/01/1900	21/06/2019	21/06/2019	0/01/1900	0/01/1900		1.3 - AREA_3	1.2 - Ricky Avinash	QG	156	1 - TAR Support
2022262	081 - FINAL APPROVAL ITP	MICRO EWR - EWR SCOPE PROJECT PORT-FOLIO	TRUE	IMPID	BP	1	0/01/1900	0/01/1900	22/06/2019	22/06/2019	0/01/1900	0/01/1900		1.3 - AREA_3	1.2 - Ricky Avinash	QG	156	1 - TAR Support
2022171	004 - Remove concrete around anchor bolts	PORT EWR - EWR SCOPE PROJECT PORT-FOLIO	TRUE	TASS	LENGKEEK STRUCTURAL STEEL	24	22/05/2019	23/05/2019	24/05/2019	25/05/2019	24/05/2019	27/05/2019	1	1.3 - AREA_3	1.2 - Ricky Avinash	QF	156	1 - TAR Support
2022171	005 - Install 4 jack supports on skirt T801	PORT EWR - EWR SCOPE PROJECT PORT-FOLIO	TRUE	TASS	LENGKEEK STRUCTURAL STEEL	16	22/05/2019	22/05/2019	24/05/2019	25/05/2019	24/05/2019	27/05/2019	1	1.3 - AREA_3	1.2 - Ricky Avinash	QF	156	1 - TAR Support
2022196	028 - FINAL APPROVAL ITP	PORT EWR - EWR SCOPE PROJECT PORT-FOLIO	TRUE	IMPID	BP	1	0/01/1900	0/01/1900	18/06/2019	18/06/2019	0/01/1900	0/01/1900		1.3 - AREA_3	1.2 - Ricky Avinash	QG	156	1 - TAR Support
2019007	006 - TEST, COMMISSION & PUNCH INSTRUMENTS (QC FINAL)	PORTFOLIO - PROJECT PORTFOLIO	FALSE	TAEC	SPIE E/I AREA-1	4.37	5/06/2019	5/06/2019	17/06/2019	18/06/2019	17/06/2019	17/06/2019	1	1.1 - AREA_1	1.27 - Konijnenburg, John	QF	133	7 - Elec & Instr
2019007	002 - DISCONNECT INSTRUMENTATION	PORTFOLIO - PROJECT PORTFOLIO	FALSE	TAEC	SPIE E/I AREA-1	2	3/06/2019	3/06/2019	5/06/2019	5/06/2019	29/05/2019	14/06/2019	1	1.1 - AREA_1	1.27 - Konijnenburg, John	QF	133	7 - Elec & Instr
2019007	005 - CONNECT INSTRUMENTS	PORTFOLIO - PROJECT PORTFOLIO	FALSE	TAEC	SPIE E/I AREA-1	12	3/06/2019	5/06/2019	15/06/2019	17/06/2019	14/06/2019	14/06/2019	1	1.1 - AREA_1	1.27 - Konijnenburg, John	QF	133	7 - Elec & Instr

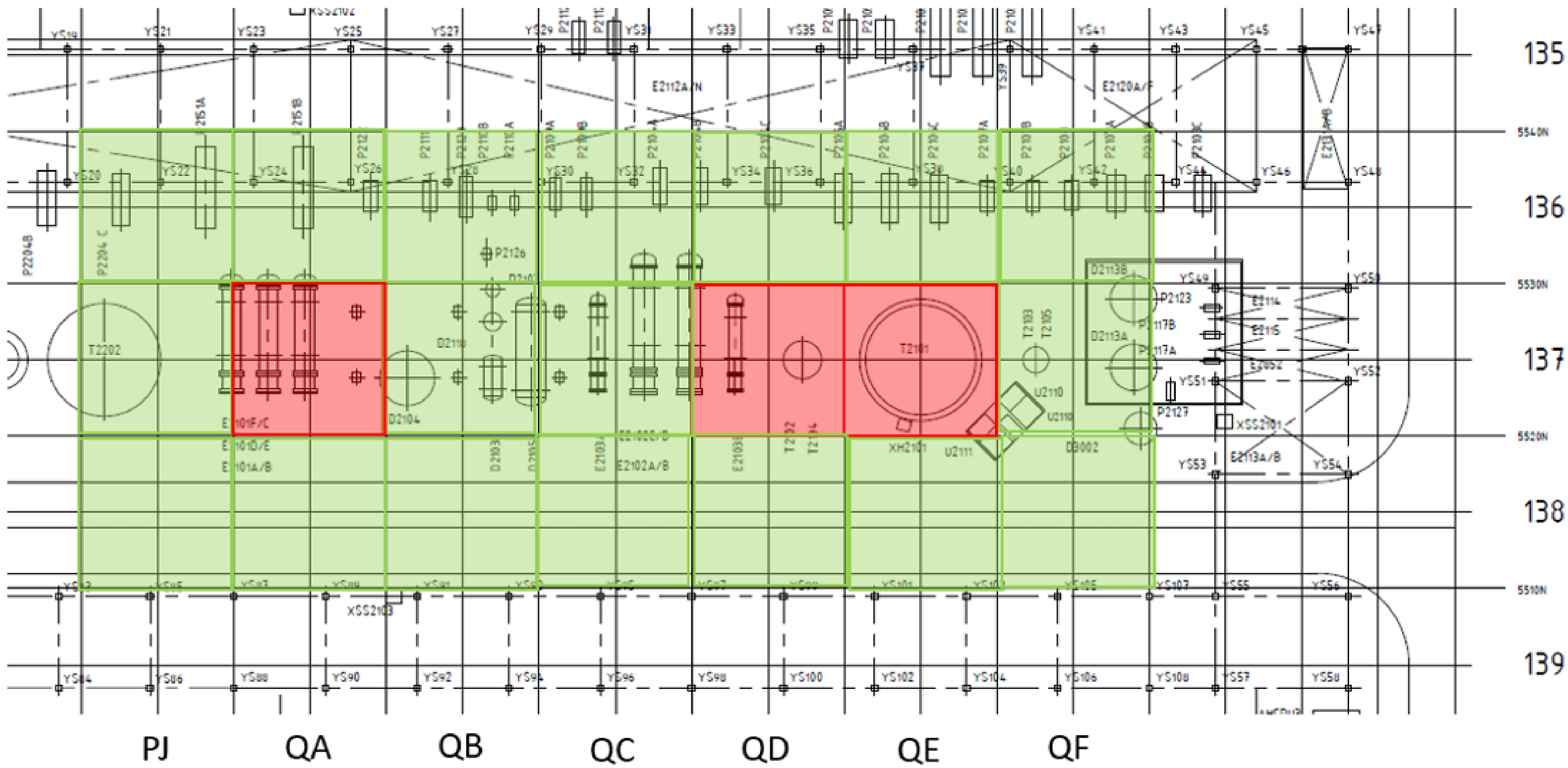
Appendix H: VBA Macros for Distribution of The Labor Over Task Duration

```
J = 1
For i = 1 To 57572
    psdate = Sheet1.Cells(1 + i, 6)
    pfdate = Sheet1.Cells(1 + i, 7)
    dur = pfdate - psdate
    totH = Sheet1.Cells(1 + i, 5)
    alpHgrid = Sheet1.Cells(1 + i, 11)
    NUMgrid = Sheet1.Cells(1 + i, 12)
    If psdate = 0 Or pfdate = 0 Or totH = 0 Then
    Else
        If dur = 0 Then
            Sheet1.Rows(i + 1).Range("A1:M1").Copy
            Sheet2.Activate
            Sheet2.Cells(J + 1, 1).Select
            ActiveSheet.Paste
            Sheet2.Cells(J + 1, 14) = psdate
            Sheet2.Cells(J + 1, 15) = totH
            Sheet1.Activate
            J = J + 1
        ElseIf dur <> 0 Then
            For K = 0 To dur
                Sheet1.Rows(i + 1).Range("A1:M1").Copy
                Sheet2.Activate
                Sheet2.Cells(J + 1, 1).Select
                ActiveSheet.Paste
                Sheet2.Cells(J + 1, 15) = totH / (dur + 1)
                exDate = psdate + K
                Sheet2.Cells(J + 1, 14) = exDate
                Sheet1.Activate
                J = J + 1
            Next K
        End If
End If
Next i
```

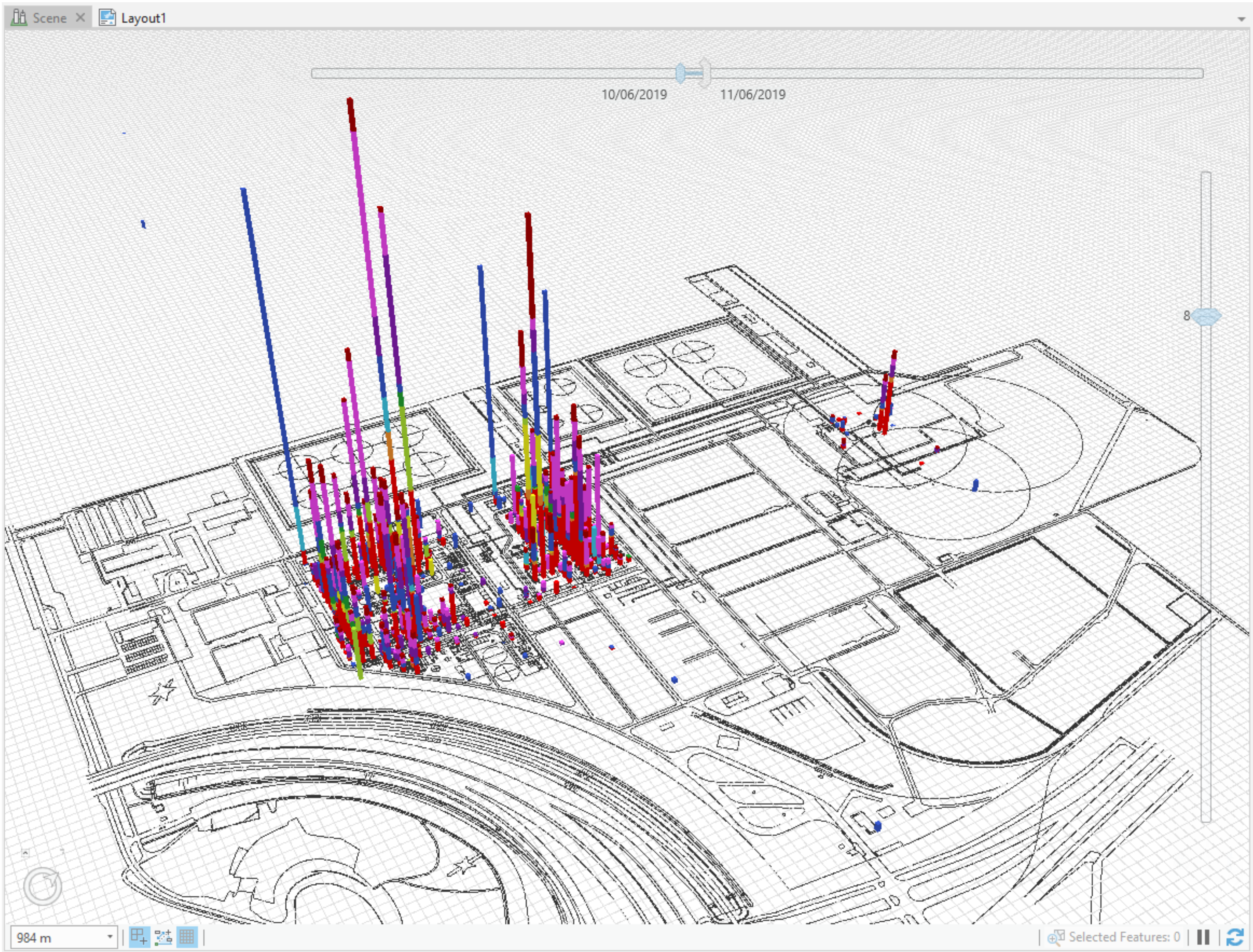
Appendix I: Supervisor-A Area Scope



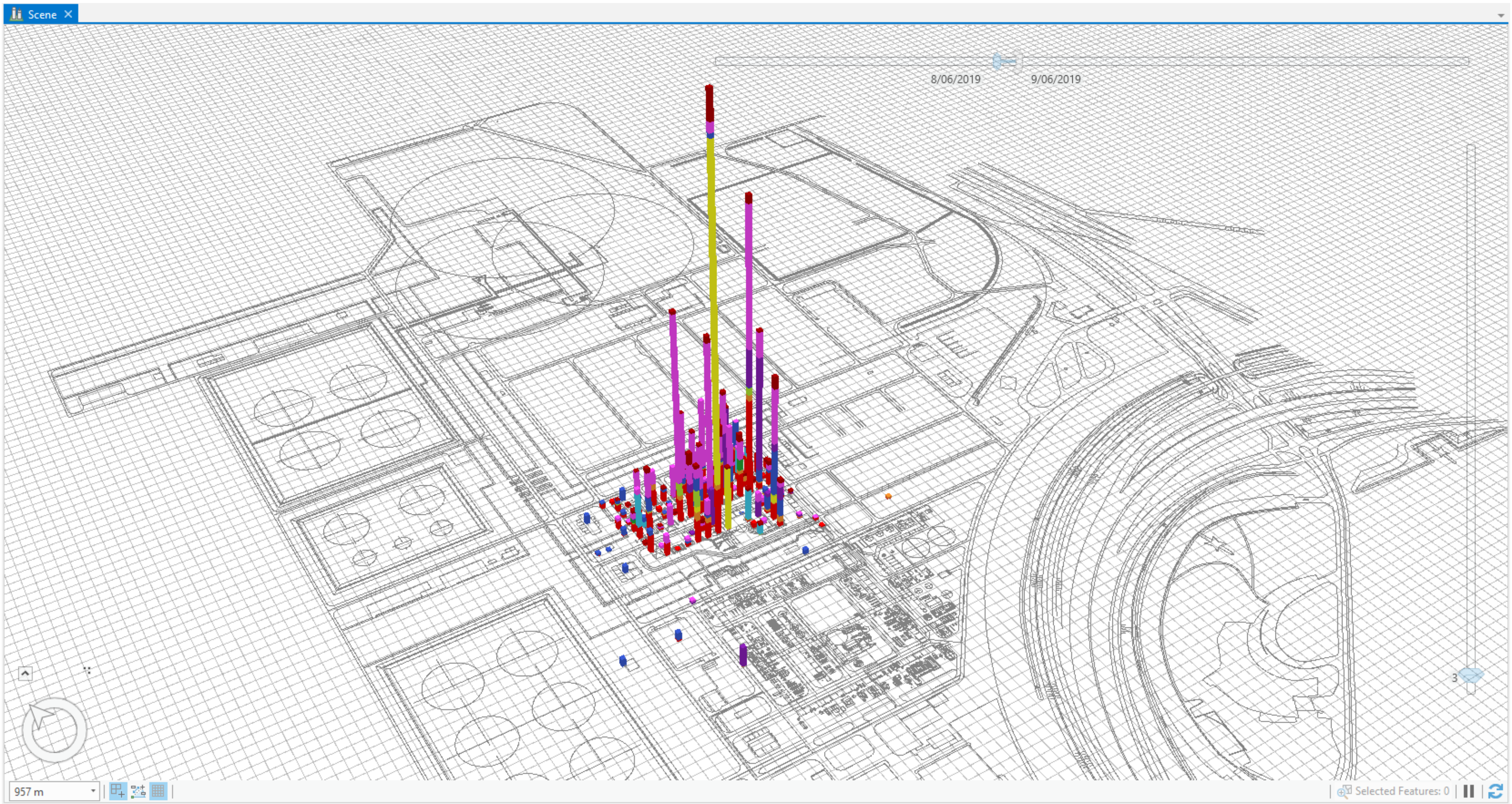
Appendix J: Supervisor-B Area Scope



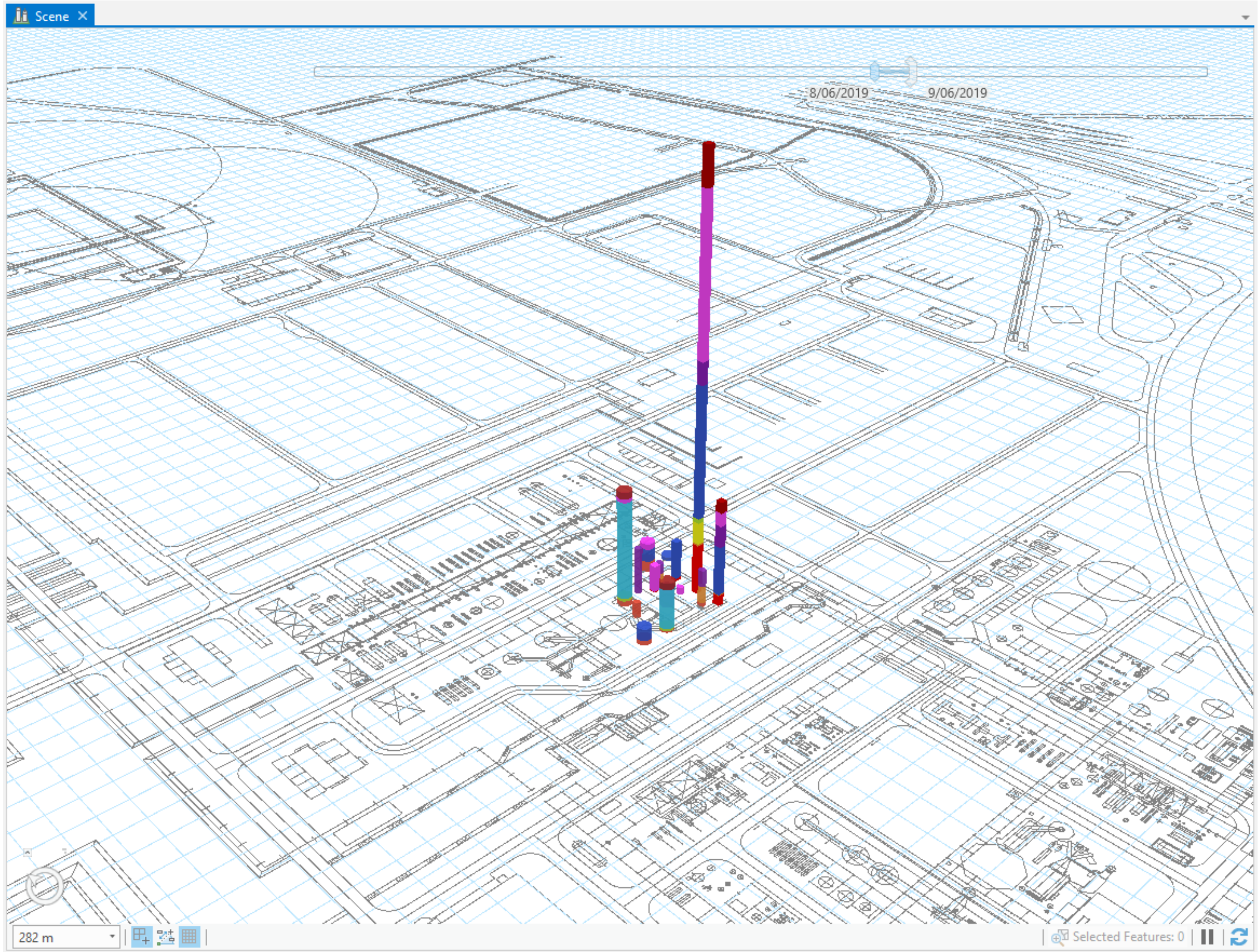
Appendix K: General Scope: Areas 1,2,3



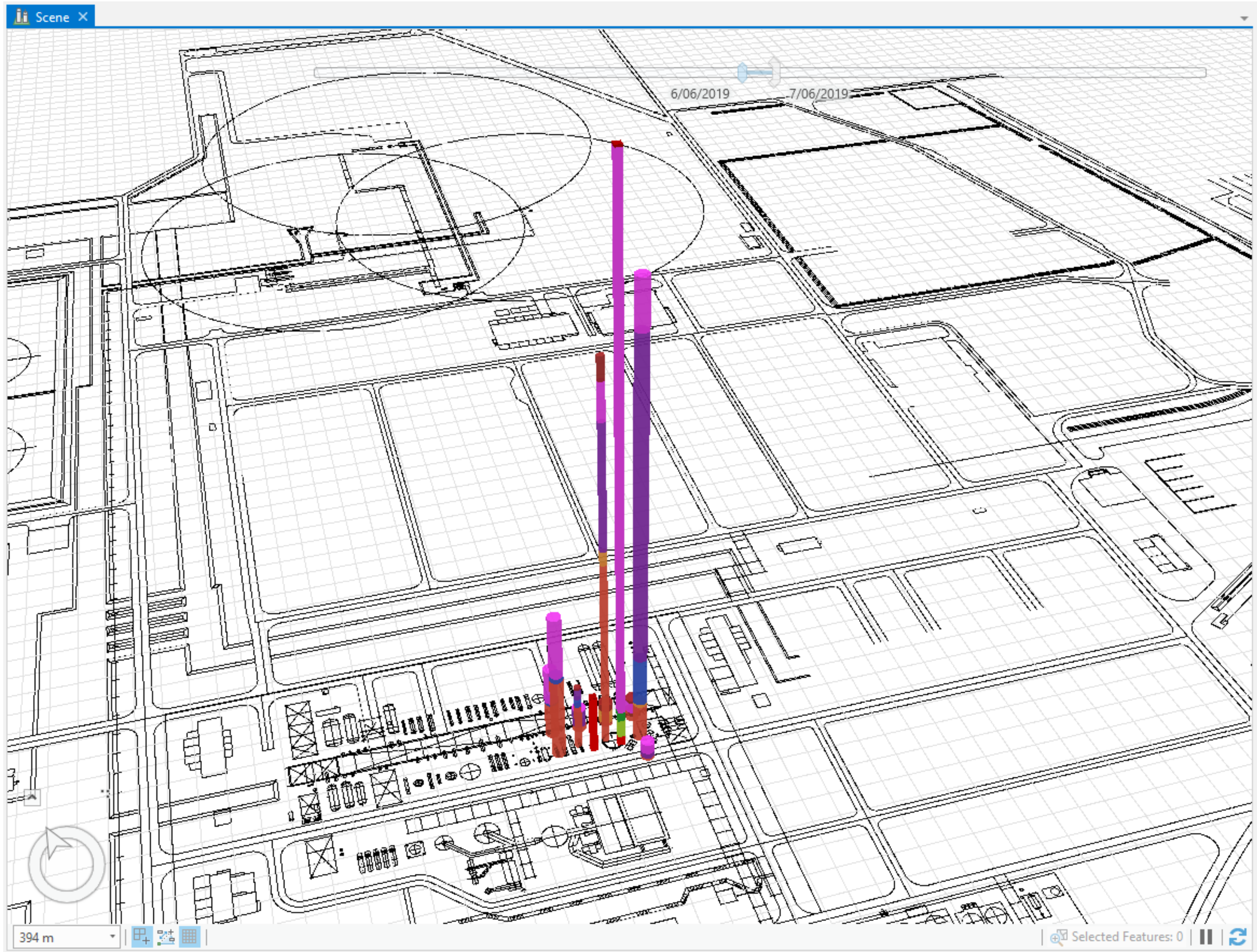
Appendix L: Area Manager Scope: Area-1



Appendix M: Supervisor-A Scope: Area-1–Focus on H2101 & Surroundings



Appendix N: Supervisor-B Scope: Area-1–Focus on T2101 & Surroundings



Appendix O: TAR Talk #13. Felipe Reinel

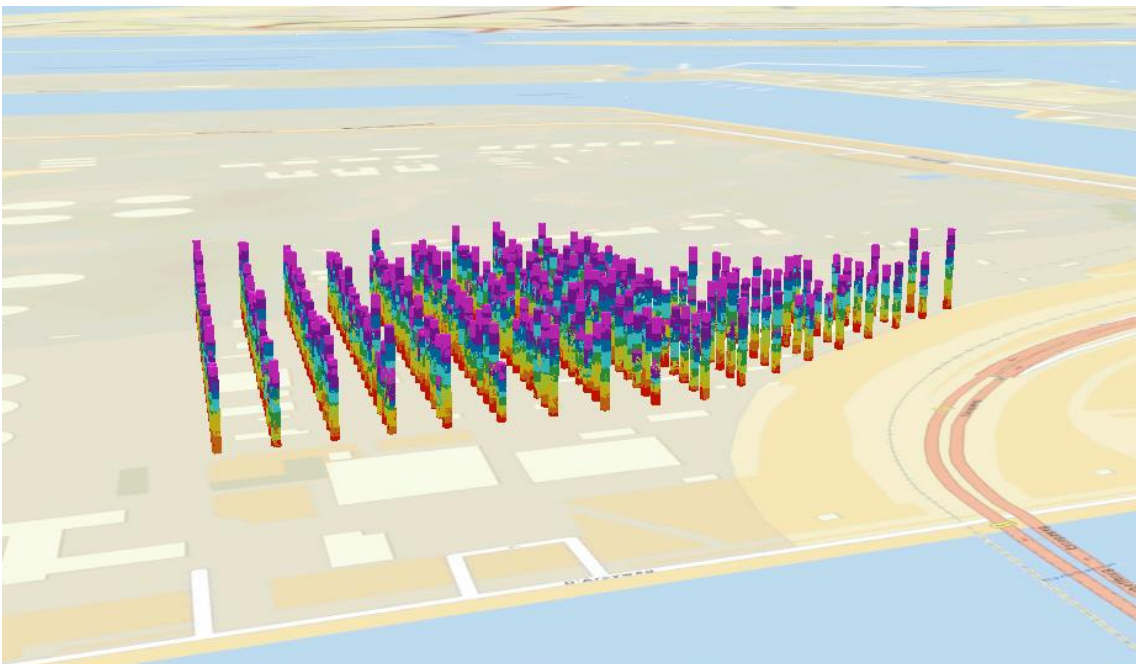
LET´S GET VISUAL...

Fast-paced, schedule-driven, high intensity, high number of tasks, and resources are just a few of the characteristics that make turnarounds so complex and exciting. As a student, with no previous experience on turnarounds, being a part of the TAR team and experience these complexities on a first-hand is a great opportunity. Therefore I would like to start this TAR talk by thanking BP Refinery Rotterdam for allowing me the opportunity to be a part of the team and to allowing me to conduct my graduation research on this exciting project.

For those of you who have not had the chance to meet me, I am Felipe Reinel, a Colombian student conducting a master’s degree in construction management at TU Delft. I started my relationship with BP Refinery Rotterdam in July 2018 doing an internship on the construction of the New Central Control Room. During the internship, I realized that Turnarounds were a recurrent topic amongst the BP colleagues. It was at this time where I started investigating and gaining interest on TAR projects. After meeting with Wim Verwijs and Jan Hendrik Bredee, a research proposal was discussed and set to start in January 2019.

The role of student researchers in construction projects is to pinpoint the complexities that characterize the project and develop an innovative method or tool that will tackle these complexities. As TAR projects are characterized by its organizational complexities, like the high level of resources and tasks fitted into a reduced space in a short amount of time, it is clear that these complexities cannot be avoided. It is, therefore, necessary to embrace these complexities rather than look for ways to avoid them.

The research to be conducted for the TAR2019 consists of developing a tool that will provide a visualization of the distribution of labor resources on the field. This tool will look to merge schedule and labor resource data with the on-site geographic reference and represent this information in a 3D model. This is especially valuable for the TAR projects because of the vast amount of information present in the project. By developing this tool, team members can visualize resource schedule and geospatial information in a simplified and interactive way and would only need to obtain the information needed from one source. The goal of this tool is to make information easily interpretable and accessible to all team members and by doing so improve organization, coordination, communication and project controls which will have a positive effect on the final productivity of the turnaround.



I want to end this TAR talk making it clear that research and the development of the tool are for the use and benefit of the TAR team. It is therefore crucial that TAR team be part of the development of the tool as together and based on your feedback, we can construct a truly valuable tool fitting yours and the team's needs. Because of this, I would like to invite the TAR team or whoever is interested in the research to pass by my workspace in TMO behind Wim Verwijs office where I can show you how the visualization tool is progressing, and we can discuss ideas to improve the tool.

I am looking forward to meeting and working with the team, and I wish you all good luck and prosperity for the TAR2019!

Appendix P: TAR2019 ArcGIS Labour Visualization Manual

To whomever it may concern this text serves as a manual to install the ArcGIS PRO software, to find and open the file that contains the project, and basic explanation on how to operate and comprehend the interface and the data visualized.

Download Software:

ArcGIS PRO (western) is available for BP employees in the BP Software Centre.

Find and Open Project:

- Project Files are shared in the drive everyone(//bp1nfcis001.ad.bp.com) "W:\TAR2019 ArcGis Labor Distribution"
- Within this folder, you will find two subfolders one for the General scope of the turnaround covering all areas and another folder for the Scope of Area-1 with more detailed visualization for Area-1 Manager, Supervisor-A and Supervisor-B who are the subjects of the research.
- **IMPORTANT:** Once you have located the file, you must copy and paste the complete folder "Initial Data" or "Update-X-XX0X2019 AFTERNOON" to your desktop. This will assure that the original scenario stays intact and will make the software run smoother as retrieving the information directly from the shared drive will make the software slow.
- The numbers in the folder name "Update-X-XX0X2019 AFTERNOON" will let you know the version of the update and the date when it was actualized. For example, first Updated set Is "Update-1-21052019 AFTERNOON"

Visualized Data:

- General Scope: Areas 1, 2, & 3 (Appendix K)

Layers	Shape of Column	Classification / Color	Pop-Ups
Total Scope Area 1, 2 & 3	Square	Discipline / Solid	Contractors

- Area-1 Manager Scope: Area-1 (Appendix L)

Layers	Shape of Column	Classification / Color	Pop-Ups
Area-1 Manager Discipline	Square	Disciplines / Solid	Contractors
Area-1 Manager OBS	Circle	OBS / Solid	Contractors

- Supervisor-A Scope: Area-1 Focus on T2101 & Surroundings (Appendix M)

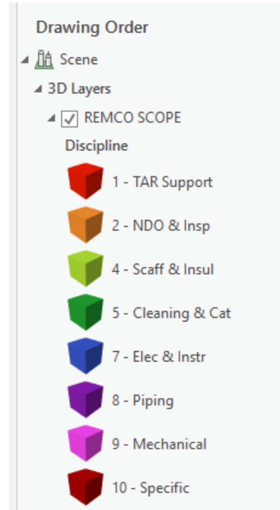
Layers	Shape of Column	Classification / Color	Pop-Ups
Supervisor-A Scope	Square	Disciplines / Solid	Contractors
Same Grid Area Scope	Hexagon	Disciplines / Transparent	OBS
Surrounding Area Scope	Circle	Disciplines / Transparent	OBS

- Supervisor-B Scope: Area-1 Focus on H2101 & Surroundings (Appendix N)

Scope	Shape of Column	Classification / Color	Pop-Ups
Supervisor-B Scope	Square	Disciplines / Solid	Contractors
Same Grid Area Scope	Hexagon	Disciplines / Transparent	OBS
Surrounding Area Scope	Circle	Disciplines / Transparent	OBS

Interface Explanation:

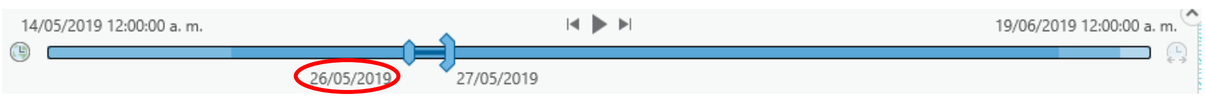
- **Drawing Order**



In the left-hand side of the interface, you can find the drawing order. Here there are tick boxes so that you can choose which layers you would like to display.

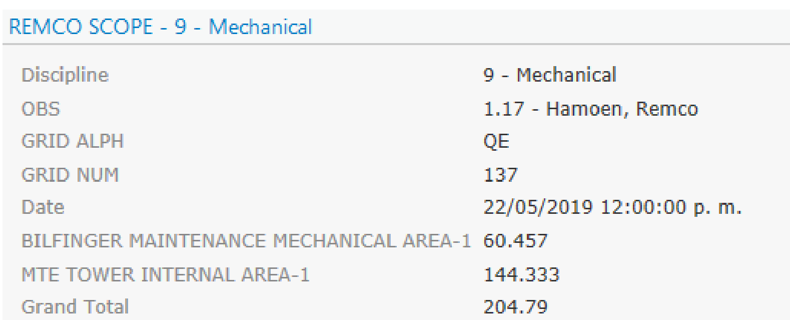
***As seen in the previous tables the General Scope has only one layer, Area-1 Manager has two layers, and Supervisor-A and Supervisor-B have three. This gives you the liberty of visualizing the data that is most interesting to you. ***

- **Time Slider**



The Time slider will be directly below the upper ribbon. With the time slider, you can slide through the whole duration of the TAR project by days. You can slide the bar or use the arrows on top of the slider. The Data that will be visualized will be indicated by the date in the lower left side as shown encircled in the picture (26/05/2019).

- **Pop-Ups**



REMCO SCOPE - 9 - Mechanical

Discipline	9 - Mechanical
OBS	1.17 - Hamoen, Remco
GRID ALPH	QE
GRID NUM	137
Date	22/05/2019 12:00:00 p. m.
BILFINGER MAINTENANCE MECHANICAL AREA-1	60.457
MTE TOWER INTERNAL AREA-1	144.333
Grand Total	204.79

Pop-ups will appear after clicking on the different shaped and coloured columns. The pop-ups show all the data that is being represented by the different columns. the following picture shows an example of a pop up from Supervisor-B Scope. This specific pop-up shows the Discipline, the OBS the Date on which the tasks are planned to be executed. And the amount of hours needed per specific contractor and the total amount of hours.

LET´S GET VISUAL...

bp

TEAM BPRR 2019
AVAILABILITY
RELIABILITY

Appendix Q: Published article in the "We are the TAR" newspaper

TAR Innovation

Let's get visual

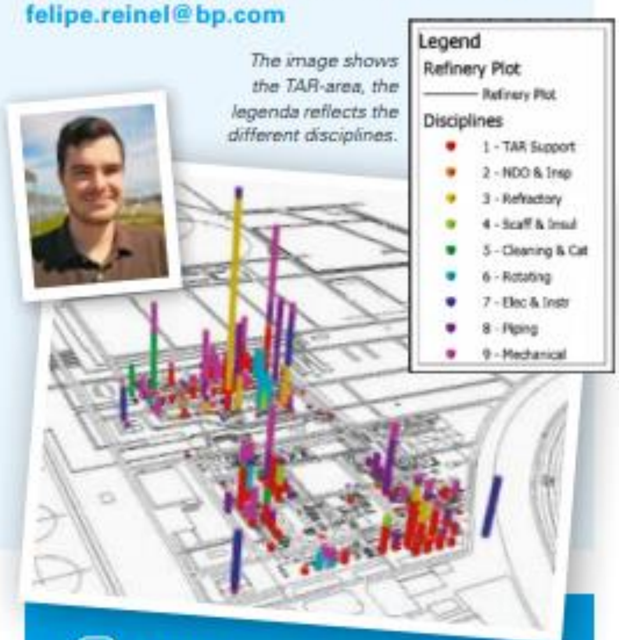
Turnarounds are highly schedule driven, require many different disciplines and involve various stakeholders. Time restriction, number of people and contractors, dynamics and the different disciplines required, make turnarounds complex to manage. Therefore, communication, coordination and organization are vital aspects in achieving a successful turnaround.

For TAR2019 a tool has been developed to provide a visualization interface of the distribution of labor resources in the field over time. The tool merges schedule and labor resource data with the geographic reference on-site and shows this information in a multi-dimensional model. That way team members can visualize labor resources, schedule, and geospatial data in a simplified and interactive way through just one source. The tool makes information interpretable and accessible to all team members. By doing so, it improves organization, coordination, communication and project controls. This will have a positive effect on the productivity and success of the turnaround.

The data shown is updated daily, including any changes in scope that might appear in the schedule. The tool was developed as part of a research to see whether this tool improves productivity or not in the execution of turnarounds, and whether it makes sense to implement the tool in a larger scale for future turnarounds.

This innovative research is for the use and benefit of the TAR team. Therefore it's crucial that the TAR team be part of the development of the tool, as feedback will increase its value and polish it into the TAR teams needs.

For more information about the labor distribution visualization tool, please contact: **felipe.reinel@bp.com**



The image shows the TAR-area, the legenda reflects the different disciplines.

TAR communication

Final editing
Hannelore Timmermans (communications & external affairs). This TAR newspaper has been drawn up with care and is for internal use only.

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Appendix R: Qualitative Questions

1. Do you coordinate your tasks with other supervisors in the same scope area? If so, how is this done?	Supervisor-A	"Only when I know the supervisor. Most times it is on the field when I find them, and I ask them what they are going to do and if we have conflict, we discuss what we can do. If it is urgent for you or if you can shift a day or if the activities can be combined. Can be with supervisor or contractor foreman directly"
	Supervisor-B	"Talking to each other. Planning to see what are. Some things are really hard to see beforehand. So the turnaround is really a day to day experience. Even if I plan something to ahead when the day comes the activity has shifted some days so it is really not a lot of planning can be done on my behalf. It is too dynamic to check Infront of the TAR."
2. What do you think are the complexities of turnarounds that make it difficult to follow the base planed schedule?	Supervisor-A	"For the furnaces especially its the amount of contractors. All the different contractors want to do their job and are going for it but if there is a contractor conflicting, they argue on who should do the task first. And it is the supervisors work to say what the priority is and who should wait. But if the supervisor is not there it depends on how the contractors behave. The difficulty is that the contractors are too focused on their scope and do not consider the priorities in general. very disorganized."
	Supervisor-B	"There are always things coming up that you have not prepared or are not aware of. Somethings that you thought were easy become really tough or tough activities turned out easy. requires the supervisors to be constantly in the field. Contractors are very bad in dealing with other contractors, so it really is the supervisor's job to be constantly making sure that conflicts do not happen and if they do the decision is not based on the contractor's desire but what the priority is. "
3. What do you think are the root causes of wasted time in labour productivity?	Supervisor-A	"The problem is always the contractor that gives you the time indication for the job. so they may say they take 2 days were in reality they spent 2.5 or 3. The duration of the task is made in the planning but it is given by the contractor so there are things we cannot control. for example operations need to cut pipe, but when they arrive the pipe is not clean enough. so there are too many variables. Contractors are very bad in dealing when not supervised, so the supervisor must always be on-field on-top of the contractors making sure they do what they are supposed to and that all conflicts are dealt with in the most advantageous way. "

	Supervisor-B	“There always are. The first three days are always hectic as people have to get accustomed to thing like were you get the permit. You can spend 20-50 minutes just to get the permit. When the people have a break it is calculated for 20 minutes but it is never 20 minutes because they walk to the break area and it takes 15 minutes and then they take their break of 20 minutes. so every break is losses productive time, but it is like this for all turnarounds.”
4. What problems did you encounter during the turnaround?	Supervisor-A	“SIMOPS in my furnace inside I had five contractors working together. They should not be working on top of each other, so a barrier was made but still contractors do not follow and walk in the unsafe areas. And a lot of different work heating welding refractory to much different work happening at the same time making turnarounds very chaotic specially the first days. you can follow the plan, but you cannot say with certainty at what exact moment the task is going to be executed. It really on the moment itself it is really hard to plan Infront”
	Supervisor-B	“We had a fire in the tower next to mine. When we opened the bottom section of the crude tower, we were expecting to clean solid but when we got there it was very sticky and only because of that it took a lot of time.”
5. Did you encounter problems where you were not aware of scope change?	Supervisor-A	“Offcourse there is also extra work that have to be done. I was aware of this so I was working Infront of Roser because I already knew that they will be critical in the future.”
	Supervisor-B	“I do not think so I did not have that much scope changes. We had some extra work in the crude tower of replacing beams but besides that not a lot of scope changes”
6. Did you encounter problems where the contractor you had to supervise was not aware of scope change?	Supervisor-A	“Yes you should always speak with the contractor they work only with an official paper letting them know that they have extra work and if you talk with them, they are usually not aware of the change. When extra work emerges it is the supervisor’s job to make sure that all the stakeholders are aware of what is going to happen.”
	Supervisor-B	“Every morning I walk to the main contractor for the tower and had discussion to see what we had to do. Because I worked only in the tower, I did not have to deal with that many different contractors as other supervisors”

7. Did you encounter problems were the contractor was not at the right place at the right time?	Supervisor-A	“I ask contractors to do tasks and continue supervising other works, when I come back, I realise that they only completed 2 of the 3 tasks. Really constant supervision is needed. Not only organization but also skills of the contractor. It is hard to tell the contractor that you need to start early the next day to catch up and when you get there the next day the contractor has not arrived. You cannot really escalate it because you have to be worried of the relationship with the contractor. if relationship is bad then contractors will make life more difficult.”
	Supervisor-B	“Not in my case again because my job was very concentrated in one place. For piping jobs on the other hand they are much more scattered through the refinery making this aspect more critical”
8. Do you consider that contractors have issues locating the work spot in the refinery?	Supervisor-A	“Most times they have work packages. But you find in the field that contractors are lost or trying to find their work spot. Even for me that I have the refinery in my head it is hard to find the exact spot were the activity must be done. If the contractors get lost, then I have to go look for them and a lot of time and effort is lost in this. sometimes the working package is not clear enough were the location should be. “
	Supervisor-B	“For me it is my job to know where things are, and where things should be. But the contractors as they are working in a new environment to them, I had to make extra efforts to get them to know where they had to be”
9. Did you encounter problems were activities were conflicting in area and time?	Supervisor-A	“Even before starting to work you can already tell that activities will be conflicting. Removing the refractory the entrance was closed and a barrier were made conflicting with my scope. The worst part is that if work is finished, they do not let me know”
	Supervisor-B	“The complete change of tower next to my scope so when I was working in a manhole, I had to take out of large amounts of material. So there is not awareness of exactly what is going on. in the surrounding areas”
10. What do you think the visualization tool is useful for?	Supervisor-A	“It is useful to see the workload that has to be executed in a certain day. You can really see if you are going to have a lot of SIMOPS or not from the tool. Also it tells you which contractors are working were and for how much time”
	Supervisor-B	“I think to get a good overview of what work has to be done on the area.so you can really see where and what hours.”

11. Who do you think are the stakeholder (users) of the tool?	Supervisor-A	“Schedulers in order to level resources. it will be useful also for general logistics and having a helicopter view on what is going on. Supervisor will be also helpful. It would be especially good for the contractor because they see the location. Supervisors normally know what they have to do and where but for contractors is different story”
	Supervisor-B	“for the managers is very useful as they are more focused on the general level. From the desk they can see where the progress is lagging, what can I do to fix and how-to level resources given changes. Also for contractors because they do not know where they have to be, and they ask a lot. The information is not visualized so they are reliant on the supervisors.”
12. How did you or how would you use the tool and how is this different from what you usually do?	Supervisor-A	“I use the tool to see the workload that is coming in the following days. Normally I look at the task, but information would be partial as the tool includes the scope of other supervisors in my surroundings and in the same area”
	Supervisor-B	“When work is more disperse it is really useful but for me it was not that hard”
13. Did you encounter any problems using the tool?	Supervisor-A	“Not after the explanation I was able to get the information out of it “
	Supervisor-B	“it is not difficult. “
14. Do you Consider that the Tool should make a differentiation on the height were the task should be executed?	Supervisor-A	“For the purpose of the tool height should not be considered. It is simple and easy as is”
	Supervisor-B	“No because most of the work is prepared in the base ground. I do not see for me how you can represent this in the height. For the SIMPOS in the planning it might be useful but for the purpose of execution I do not think it is necessary the tool is giving you sufficient information.
15. How would you improve the visualisation tool for future turnarounds?	Supervisor-A	“Implement on a general level not only for area manager and supervisors, generally the BP employees are very familiar with what they have to do as they know the plant and have been planning for many months. But the contractors are the ones coming to a new environment and are the ones who have to deliver. If the tool is implemented for the contractors the difficulty of the job would decrease as contractors would at least have a better idea and representation of what they have to do when they have to do it and what should they look out for if there is scope next to their area off course.“
	Supervisor-B	Do not know how to

16. The goal of the tool was to reduce wasted time by improving communication and coordination in the execution phase, do you think that the tool can be used for other aspects?	Supervisor-A	"Yes, I would use it in work preparation to coordinate exactly what we are going to do. Planning phase to resource planning and constructability. If it is given to the contractor. When you visualize the peaks and the contractor are aware"
	Supervisor-B	"Safety supervisors can see the peaks and the labour distribution and based on that have a better plan on where they have pay extra attention."
17. The goal of the tool was to reduce wasted time by improving communication and coordination in the execution phase? Do you think that the tool can be used for other phases?	Supervisor-A	"Planning phase could be very useful. Also very interesting to see the 3D EVA so I can see what I did and what I had to do. The problem with this 3D EVA is that you can really pinpoint that to me because it is affected by so many different factors. But I think that the really big added value is in resource levelling."
	Supervisor-B	planning for sure.

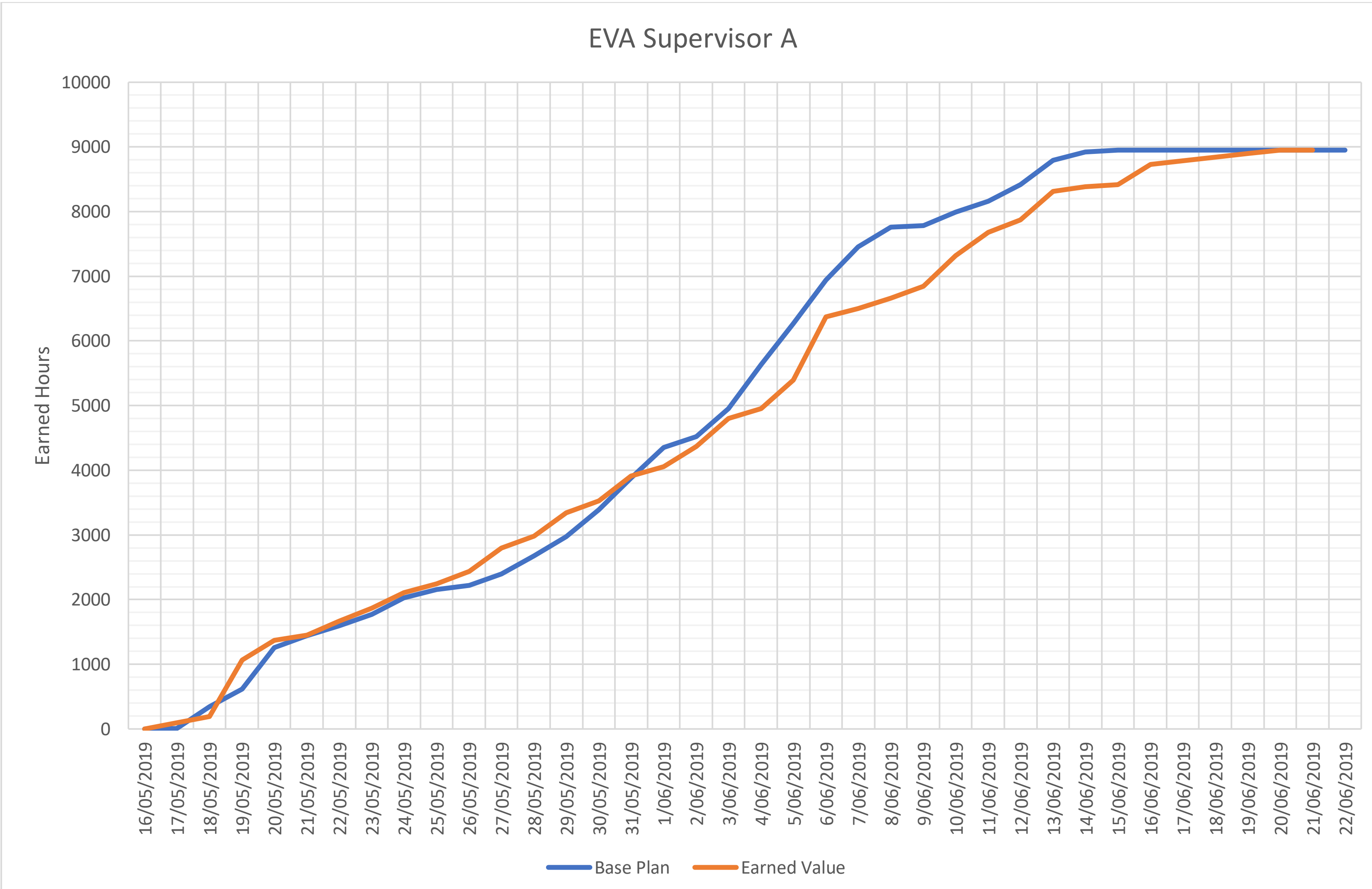
Appendix S: Quantitative Questions + Comments

1. Do you consider that Roser OR Primavera P6 are lacking in the representation of spatial data (where)? 0-10	Supervisor-A	"Too much information, I have to export data to excel and I have to delete a lot of useless information. For me it is not that bad, but a lot of colleagues are struggling to take information out from Roser. Normally the location I use is the equipment tag, but I have to base on my own knowledge to now where things are. "	6
	Supervisor-B	"I do not like the schedules that are in primavera for me it is too big, and there is too much information for me. To check the data, you really need to dedicate some time to understand what you are looking at. I really like of the tool that it is an overview and simplified information. Because its small and simple. "	7
2. To what degree are you aware of tasks that are not in your scope but are executed in your scope area? 0-10	Supervisor-A	"Sometimes it is difficult to know because there are so many changing factors and so many things that do not depend on you. Also, you are very focused on you own scope and hope that other supervisors are doing their work correctly as well"	4
	Supervisor-B	"I ask the supervisors if they have work in my area. I know if they have a task in my area, but I am not aware of what it is they have to do. SIMOPS is always something to consider, but the information comes from talking not from the schedule"	6
3. Do you consider that during the execution phase of turnarounds there are coordination problems? 0-10	Supervisor-A	"There are Coordination problems, but it is usually the contractor. Because it is my job to make sure they are working the coordination is also influenced by who the supervisor is and how involved he is. I feel that I have to be constantly there because if you let contractors make decisions for themselves things will go bad"	7
	Supervisor-B	"We did the best we can to make the preparation as good as we can. But you get 1000 people in the area at day one. As time passes it starts looking more like a turnaround because people start adapting and are more aware of what they have to do"	8

4. Do you consider that during the execution phase of turnarounds there are communication problems? 0-10	Supervisor-A	“It depends on who you are working with we had a lot of different nationalities from the contractors, so you find people talking other languages or who did not understand you very well. This is always a problem”	6
	Supervisor-B	“I am always talking to everyone sending emails. Communication is very important factor. Also, because my scope was very focused, I already knew which supervisors I had to talk with”	2
5. Do you consider that during the execution phase of turnarounds there is lack of awareness? 0-10	Supervisor-A	No Comment	3
	Supervisor-B	“Everyone is so focused on what they have to that people do not really look at that. If everyone is working in the right way, then there is little need for this awareness unless it has to do with safety situation. Form me when I was finishing my tasks, I got assigned to help other supervisors and at this moment it was the first time I looked at other work”	6
6. Do you consider that the tool could replace previous mentioned sources of information? 0-10	Supervisor-A	NO. Roser has all the details so the visualization tool is more of an overview tool. But when very detailed information is needed you must go back to Roser. Also, for primavera it is difficult because it only shows the main contractor and not the different subcontractors. So, if the task is 95% done for example inspection work the data does not show who the subcontractor in charge of that 5% is. if I am familiar with the scope, I can use the tool but if I need very detailed information, I have to look at Roser. pictures and plot plans are also in Roser and might be difficult to visualize in the tool”	0
	Supervisor-B	“Not yet. The detail you still get from other programs. Maybe in the future but the tool is interlinking tool between the Roser and primavera.”	0
7. How straight forward (Clear) is the information of the tool presented (user friendliness)?0-10	Supervisor-A	“Clear and fast to read”	7
	Supervisor-B	“When you look at it you have the discipline colors and it is easy to get a feeling of the amount of work. Also, the popups resume data very well”	8
8. Do you consider that the visualization tool enhances coordination? 0-10	Supervisor-A	“I think the potential in the planning phase is 8 but during execution 6 because when you look at the tool on the day or one day before it is already difficult to change”	6
	Supervisor-B	“Definitely, but the real results would be seen if all the people involved had access because it is not only depending on me only. we need the contractors	9

		to get this information on where they must be and what they have to do for each day. In this case It would be very beneficial”	
9. Do you consider that the visualization tool enhances communication? 0-10	Supervisor-A	No Comment	7
	Supervisor-B	“When everybody is looking at it definitely but from one side it is difficult”	8
10. Do you consider that the visualization tool creates spatial awareness? 0-10	Supervisor-A	“That is the point of the tool and it does it very simple it is like using google maps”	9
	Supervisor-B	“It shows you exactly the amount of work in the grid system, no other tool does this”	10
11. Do you consider that the visualization tool reduces wasted time? 0-10	Supervisor-A	“You find a lot of contractors lost in the refinery and wasted time traveling that the tool should help with”	7
	Supervisor-B	“You can see from the overview where you have to work. Reducing time in searching for the place maybe it is interesting to give printouts to the supervisors on where they have to work so they do not depend on a list with no visual representation.”	8
12. Do you consider that the visualization tool improves Labor Productivity?0-10	Supervisor-A	“Yes, but much more effective on contractors who are not familiar with the refinery Also for contractor mangers as the overview will help them planning how to distribute workers depending on the amount of work.”	7
	Supervisor-B	“Similar to the wasting time. But I think the tool will help productivity more in the planning phase were resources can be planned better because of the peaks that the tool represents”	8

Appendix T: Supervisor-A Earned Value Analysis



Appendix U: Supervisor-B Earned Value Analysis