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A Project Management Framework for Fuel Conversion Projects

A case study

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ABSTRACT:
The push towards sustainability and the improved availability of natural gas has resulted in an increase of fuel conversions of engine power plants. Fuel conversion of a power plant may result in financial, operational, or environmental benefits. Fuel conversion projects can be classified as retrofit projects which can require a different project management approach compared to new build projects. The aim of this research is to study the project process of a company that performs fuel conversions of existing engine power plants. In line with the aim the following research questions emerged, RQ1: what does the fuel conversion project process look like? and RQ2: how can a project management framework support knowledge transfer of fuel conversion projects? Based on the current project process a project management framework is developed to create a defined structure that can support the execution of upcoming projects. The second objective of the framework is to facilitate knowledge transfer of fuel conversion projects to increase the organizational capacity of performing the projects. The research method used in the research is the case study method. The data collection included semi-structured interviews, company documents, observations, and a workshop. The developed framework complements the existing project model in use by specifying the project delivery of fuel conversion projects by dividing the delivery into five phases. The framework includes a summarizing table, visualization of the main project activities, descriptions of each phase, challenges, and success factors of fuel conversion projects. The framework enables knowledge transfer by working as a knowledge market where experienced team members can share their knowledge to less experienced ones. The research concluded that fuel conversion projects are susceptible to challenges regarding tight schedules, cost deviations, engineering quality, combining new designs with old designs, material and site manpower availability, and occurring changes during the project. Understanding the scope and requirements thoroughly, accurate information about the existing power plant, and early planning and preparations can mitigate challenges and support project success.

KEYWORDS: Fuel Conversion, project management, project management framework, knowledge transfer, retrofit projects

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ABSTRAKT:
Utvecklingen mot hållbarhet och den förbättrade tillgången av naturgas har resulterat i en ökning av bränsleomvandling av motordrivna kraftverk för elproduktion. Omvandling av ett motordrivet kraftverk för att använda hållbarare bränslen, så som naturgas, kan medföra ekonomiska, operativa, eller miljövänliga fördelar för kraftverkets ägare. Bränsleomvandling av ett kraftverk kan klassificeras som ett eftermonteringsprojekt, ett så kallat ”retrofit project” på engelska. Dessa projekt skiljer sig från traditionella projekt där produkten byggs upp från grunden, och kan därför behöva alternativa projekthanteringsmetoder. Syftet med denna avhandling är att undersöka processen bakom bränsleomvandlingsprojekt vid ett företag som genomför dessa. Vidare är syftet att utveckla ett projekthanteringsramverk för att stöda projekthanteringen. Projekthanteringsramverket ska också främja kunskapsöverföringen av projekttypen inom företaget för att öka förmågan att genomföra projekten. Utgående från syften utvecklades två forskningsfrågor, hur är processen bakom bränsleomvandlingsprojekt uppbyggd? och hur kan ett projekthanteringsramverk främja kunskapsöverföringen av bränsleomvandlingsprojekt? Denna avhandling är kvalitativ och använder fallstudie som forskningsmetod. Datainsamlingen skedde genom semistrukturerade intervjuer, dokument, iakttagelser och en workshop. Projekthanteringsramverket utvecklades i enighet med företagets projektmodell genom att dela in genomföringsfasen av bränsleomvandlingsprojekt i fem mindre faser. Ramverket består av en sammanfattande tabell, en visualisering av det huvudsakliga projektinnehållet, beskrivningar av faserna, utmaningar samt framgångsfaktorer av bränsleomvandlingsprojekt. Ramverket främjar kunskapsöverföring genom att fungera som en kunskapsmarknad där erfarna medlemmar inom projektgruppen kan erbjuda kunskap till medlemmar i behov. Genom informationen delad i projekthanteringsramverket kan alla medlemmar inom organisationen upprätthålla samma kunskap. Slutsatsen av avhandlingen antyder att bränsleomvandlingsprojekt påverkas av utmaningar, så som tidskrav, avvikelser i kostnader, designkvalitén, kombinerande av ny och gammal design, tillgång av material och arbetskraft, och förändringar inom projektet. Samtidigt konstaterades att fullkomlig förståelse av projektomfattningen, tillräcklig och noggrann information om det existerande kraftverket, och tidiga samt omfattande förberedelser kan hjälpa i hanteringen av utmaningarna och uppnå framgång i projekten.

Nyckelord: Bränsleomvandling, projekthantering, projekthanteringsramverk, kunskapsöverföring, eftermonteringsprojekt

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Abbreviations

BTU – British Thermal Unit

CI – Compression Ignition

DF – Dual Fuel

EPC – Engineering Procurement Construction

HFO – Heavy Fuel Oil

HMI – Human Machine Interface

HS – Harmonized System (code)

HSE – Health, Safety and Environment

ICE – Internal Combustion Engine

ITP – Inspection and Test Plan

MWh – Megawatt Hour

NG – Natural Gas

PM – Project Management

PMF – Project Management Framework

PMO – Project Management Office

SI – Spark Ignition

SM – Site Manager

1 Introduction

Engine power plants for electricity production can be converted to run on a different fuel source. In a project like this the existing power units and facility must be modified to be able to run on another fuel type. This makes power plant fuel conversion projects fall under the retrofit project category since an existing application is modified from its original state (Merriam Webster 2021). Retrofit projects are different compared to new build projects because their planning and execution is affected by the constraints of the existing facility, time restrictions, and fitment of new and old equipment to name a few (Sanvido & Riggs 1993). Retrofit projects are mostly implemented when performance or value of the current application is declining but the initial investment must be secured (Fox 2003). The different challenges of retrofit projects require the support of suitable project management methodologies for the projects to be successfully managed.

According to Kerzner (2010) executing project management with the help of project management methodologies is currently popular but there has been an increase in adopting project management frameworks instead. A framework is a support structure which provides principles, concepts, templates, and tools for project teams to excel in project execution. Frameworks are more flexible than methodologies by being more adaptable and customizable for responding to the project's needs. Shenhar et al. (2015) suggest that the traditional "one-size-fits-all" approach for project management does not work for modern dynamic project management environments. Therefore, organizations should focus on creating methodologies or frameworks specifically designed for their specific project needs.

There are scarce amounts of research studying the fuel conversion of diesel engine power plants being modified to run on another fuel source, how it is done in practice, the challenges, benefits, or disadvantages. Studies can be found on diesel engines in marine applications being converted to natural gas (NG) or dual fuel (DF) operation (Antunes et al. 2012; Banawan et al. 2010; Elkafas et al. 2020; Deal 2013; Lazard 2017; Stornoway Diamond 2013). These studies can give some indication on the benefits and challenges of converting power plants as well since engines used in power plant applications are like those of marine applications (Kuiken 2016). Similarly, there is very limited number of studies on the project management and optimal structure of retrofit projects (Fox 2003), especially in the energy production field. Consequently, there seems to be a quite large gap in the research in these fields indicating the value of new research.

1.1 Background

One of the markets the case company of this research is involved in, is designing, and delivering engine power plants for electricity production. The company offers new build power plants but also upgrades to existing plants. The company has a project management department, here after referred to as case department, for the power plant upgrades. These are projects that upgrade certain required systems or parts of a customer's power units and power plants for the customer to gain benefits in commercial, operative, or environmental aspects. One of their current key markets is fuel conversion projects where the power plant is modified to run on a more sustainable fuel source, currently NG. Tighter emission regulations, the desire to reduce operational cost and increased accessibility to NG has sparked the interest in fuel conversions. The company forecasts the demand to increase further in the future.

1.2 Research objective

The company has executed several successful fuel conversion projects already, but the case department lacks a clearly defined way of working for the project type. Furthermore, a large amount of the fuel conversion project knowledge is only known by a minority of people within the department. This forms the following research questions of the thesis,

RQ1: What does the fuel conversion project process look like?
RQ2: How can a project management framework support knowledge transfer of fuel conversion projects?

The objective of the research is to create a project management framework (PMF) based on the current project process. The aim of the PMF is to describe and visualize fuel conversion project process to support the delivery and to facilitate knowledge transfer of the project type within the case department.

The research is qualitative, and the research method is the case study method with the unit of analysis being fuel conversion projects. The data is collected through semi-structured interviews, case company documents, observations, and a workshop. The PMF is created based on the interviews, material provided by the case company and supported by the literature review. Once the preliminary version of the framework is constructed a workshop is held with the stakeholders where there is opportunity for further refinement of the framework.

1.3 Research delimitations

The research is limited to the fuel conversion project type only, even though the case department executes other project types as well. Therefore, the data collected from the interviews is only from this project type. The PMF will be tailored to serve this project type and should not be applicable to other project types, at least not in its entirety. The research focuses on the scope of the delivery part of the project which the case department is responsible for. This means that the sales phase and the warranty phase are not included in the research. Furthermore, the developed PMF must be applicable to the project management model in use at the company.

1.4 Structure of the thesis

The thesis is structured as following. After this introduction to the subject and the research aim, the theoretical framework is presented. The theoretical framework studies four different topics, retrofit projects, fuel conversion projects, knowledge transfer and project management frameworks. The theoretical framework is followed by a chapter presenting the research method in detail. The fourth chapter presents the PMF developed based on the data collection thus, answers the first research question as well. The fifth chapter discusses the developed PMF and answers the second research question. The final chapter of the thesis concludes the research and presents suggestions on future research.

2 Theoretical framework

This chapter explores the nature of retrofit projects and how retrofitting power plants to run on another fuel source can provide benefits like increased performance, cost efficiency, and environmental benefits. In addition, the chapter explores knowledge transfer and project management frameworks. The topics are introduced and research on the topics are assessed and compared to each other to gain understanding of key points.

2.1 Retrofit projects

Marriam Webster Dictionary (2021) defines *retrofit* as, "To furnish (something, such as a computer, airplane, or building) with new or modified parts or equipment not available or considered necessary at the time of manufacture." Therefore, a retrofit project is a project where an existing building, power plant, facility, marine vessel or other is modified to answer to the customer's requirements (Sanvido & Riggs 1993; Banawan et al. 2020). According to Fox (2003), retrofit projects are mostly executed in construction, manufacturing, and process industries. Retrofit projects are implemented when financial gains, environmental benefits, increased capacity, improved reliability, quality improvements, new technology and increased safety are wanted for an existing facility or system (Sanvido & Riggs 1993; Fox 2003). From a power plant perspective, retrofit projects are generally implemented when there is a need for improving availability, reliability, efficiency, output and or operational flexibility (Botello & Valdivia 2018). Retrofit projects can have more uncertainty and often include more challenges compared to new build projects. These are some of the key factors why organizations tend to avoid retrofit projects.

The scope of a retrofit project differs significantly from original or new build projects where the solution is built up from scratch (Sanvido & Riggs 1993). In retrofit projects the project team is forced to work within the realms of an existing application and try to fulfill the customer's requirements without affecting the existing application's functions or capabilities. Therefore, retrofit projects are often more difficult to perform since predetermined factors impact the execution (Sanvido & Riggs 1993; Fox 2003). Retrofits are applied to pre-existing facilities and this result in different constraints. Retrofit projects are often affected by lack or limited information of the pre-existing facility. Frequently, there is limited information of the current state of the facility and if the facility is already modified after the initial build, there might be lack of documentation or updated drawings. Retrofit projects are also heavily affected by space restrictions. The designed retrofit solution must be applicable to the current facility and equipment while the project must allow the facility to be run as close to normal as possible. Also, the commissioning of retrofit systems and material will include the re-commissioning of older systems. The difficulty of adding the solution increases with the complexity of the required modifications. Furthermore, retrofit projects usually have tight demands regarding completion time since the existing facility is in use. This is especially emphasized for factories and power plants where downtime of equipment is expensive for the customer and can result in revenue losses, sometimes even of several hundred thousand of US$ (Botello & Valdivia 2018). Finally, several challenges are introduced in the working environment of the construction of the modification for example, unsuitable working environment due to climate or noise, lack of safety, equipment not fitting, fire or explosion danger to name a few (Sanvido & Riggs 1993).

Sanvido & Riggs (1993) studied retrofit techniques and success factors for retrofit projects by conducting a questionnaire of 16 different projects, more specifically one industrial plant, two power plants, four commercial facilities, and nine oil refineries. The research concluded that creating a diverse project team with experience of retrofits is one of the most crucial aspects of success in retrofit projects. The project team dynamic must work and the whole project team should be created and be actively included in the project already at project initiation. An efficient, confident, and well communicating project team can adapt to change, be flexible and make quick decisions, traits that are essential in retrofit projects. Similarly, Botello & Valdiva (2018) point out the significance of good communication between stakeholders for project success. In addition, defining the project requirements and carefully planning the project scope are considered as project success factors.

Moreover, the projects emphasized the importance of using credited subcontractors and making background checks of new ones (Sanvido & Riggs 1993). A common technique in procurement was to buy low-cost key material and equipment in excess quantity to have spare material available. Also, buying important material early was proven common between the projects. Regarding the collection of information about the existing plant many projects exercise plant visits where designs could be observed and analyzed at the actual location. During plant visits, crucial information about the facilities and equipment can be attained from the owners. Furthermore, this forms a better relationship and foster communication with the owner. Schedule and space constraints can be battled by executing the project during a normal maintenance break since the plant or facility is down at least in some regard during this.

2.1.1 Risk and change management in retrofit projects

Fox (2003) argues that retrofit projects are more applicable to risks than new build projects. All projects have risks but due to the nature of retrofit projects where multiple stakeholders, information challenges, more time restrains, fitment of new and old together, design complexity etc. increase the number of risks and generate higher possibilities for risks happening. These factors put stress on the project team and poor decisions can be made in an environment like this. Therefore, the organization and project team must have comprehensive risk management in place to answer to risks. The research emphasizes the categorization of identified risks in order of their severity to the project's success. The risk management should focus on the risks with the worst effect and highest possibility of occurring since the number of risks in projects are too high to deal with every single one.

The following risks are common in retrofit projects (Fox 2003). In the beginning of the project, the requirements and objectives of the customer and project stakeholders are not defined adequately and there can be varying aspirations of the project between stakeholders. Unknown complexity of the project leads to risks regarding resource allocation and lack of information. Similarly to Sanvido & Riggs (1993), Fox (2003) recognizes the risk of insufficient or complete lack of drawings of the facility's initial or current design. Furthermore, another risk is the unpredictable information regarding the current state of the facility. There are also risks of the facility not fulfilling health and safety regulations with the retrofit design. Also, there is significant risk in utilizing new technology in the retrofit project as it might not be applicable to the current applications. Finally, there are several risks associated with fixed execution dates since many tasks need to be fitted into the timeframe. Once the project end date is determined, delays in project authorization and permits for project can result in significant delays. Material, equipment, sub-contractors, and site personnel may not be available on execution dates. The construction on site can be affected by changes of allowance to work at site and less significant delays all affect the project schedule.

Retrofit projects are more prone to changes during the project lifecycle which is another characteristic caused by the nature of the projects (Fox 2003). If changes to project design, schedule or tasks are needed during the planning phase of the project they are naturally embraced however, the later in the project lifecycle the change is needed it is generally more expensive to react to the change. Therefore, change management should be part of retrofit project management. Retrofit projects are often unique and seldom repeated at least in their entirety thus, there is limited experience to be used from previous projects. This results in the project often change throughout the pipeline because certain aspects could not be predicted in the planning phase. The need for change is recognized later in the project when some aspects of the design is not adaptable to the existing plant, when improvements are recognized, safety concerns arise, customer identifies other parts of the plant could be upgraded, and so on.

As a rule of thumb, changes that arise after the engineering and design is finalized should be avoided and prevented since every change affect the project scope, budget, and schedule in some way, most in a negative way (Fox 2003). There are still changes that require consideration and the most crucial one is changes that aid the customer requirements to be met. Even if the budget and cost are met the project cannot be considered completed if the scope is not fulfilled. Changes that could contribute considerable advantages to the project for example, boost in completion time or reduction of costs would be of interest to execute. Similarly, changes that benefit the customer for example performance increase and thus, could benefit the project organization financially should be considered. To be noted, these types of changes can be assessed and if they are possible to execute after project completion it should be considered. Finally, it is sensible to implement changes that support safety and environmental attributes.

2.2 Fuel conversion of power plant engines

The world continuously move towards sustainability and the transfer to renewable fuel sources is a must however, it is practically impossible for the renewables to answer to the worlds energy demand by being the only fuel source by the targeted 2050 (Boretti 2020). To enable the shift towards renewable energy source, traditional fuel sources and production techniques are still needed but where sustainable fuel sources can be used, they should. Therefore, the internal combustion engine (ICE) is still useful in the future if the emissions can be mitigated with sustainable fuels as alternative to the popular diesel. The ICE is especially useful as an energy load balancer for wind and solar power plants since the energy storage capabilities are limited (Boretti 2019; IGU 2010; Podesta & Wirth 2009). Unfortunately, there is a decrease in the popularity to improve ICE engines even though there is clearly a need for efficient engines utilizing more sustainable fuels.

There has been an increase of interest in NG as an alternative fuel for ICEs in power plants (Lavoie et al. 2017). Mainly, the increased availability, the decrease in price, and the environmental benefits of NG as a fuel source stand the reason for the increase. The decrease in price of NG can be seen in decrease of a power plants capital costs (IGU 2010). The capital costs of power plants running on NG are less than 50% of the capital costs of coal power plants, about 30% of the capital costs of nuclear power plants, and 20% of the cost of onshore wind power plants. NG engines run cleaner than diesel engines resulting in longer maintenance intervals and thus, lower maintenance costs (Banawan et al. 2010; Elkafas et al. 2020). Furthermore, NG power plants are efficient in performance. For example, NG power plants are 40% more efficient than coal-fired power plants (IGU 2010).

A power plant running on NG have significantly less emissions compared to other fossil fuels. For example, modern combined-cycle gas turbine power plants produces less than half of the CO_2 compared to power plants running on coal (IGU 2010). For ICEs running on NG instead of diesel, studies show a decrease of 20,1% in total emissions of which the following was reduced 85,5% CO_2, 98% NOx, 99% SOx, and 55,7% particular matter (Elkafas et al. 2020). It should be noted that this was measured of a fuel converted large dual fuel engine in marine application, running a combination of 98,5% NG and 1,5% marine diesel oil. Another study of a converted marine engine showed the following reduction, 10% CO_2, 72% NOx, 91% SOx, and 85% particulate matter (Banawan et al. 2010). In 2019 NG was responsible for 21,6% of the worlds CO_2 emissions from fuel combustion while oil was responsible for 33,7%, coal 44%, and 0,7% was other fuels (IEA 2021). These studies indicate significant environmental benefits that could also be present when converting diesel ICEs of engine powerplants.

NG is attractive since it is available to use now and already heavily researched compared to renewable fuels. Additionally, NG is possible to make from different sources (IGU 2010). The production of NG is estimated to increase with new sources, both traditional and untraditional. In 2019 NG held a 16,4% share of the global total final energy consumption (IAE 2021). The three biggest sectors using NG in 2019 where industry which stood for 37,6%, residential was the second largest sector by 29,7%, and transport was responsible for 7,3%. However, this is for all types of power production using NG not only ICEs.

It is noteworthy that NG is still fossil fuel and is a finite fuel source thus, it is better to consider NG more of a transition fuel in the shift towards completely renewable fuel sources (Podesta & Wirth 2009). The focus should be on incorporating as much NG as possible in the power production to reduce the use of oil and coal. Especially old coal-fired powerplants not applicable to carbon capture and storage technologies should be de-commissioned. Furthermore, NG power plants can boost the market for renewable energy such as wind and solar power by acting as load supply at peak demand situations.

2.2.1 Natural gas engine operating principle

Engines can be converted from diesel into two types of NG engines, spark ignition (SI) engines and compression ignition (CI) engines (Banawan et al. 2010). The NG SI engine runs on only NG by the Otto principle, which means that the fuel is ignited by a spark plug. (Kuiken 2016, p. 96). In this type of engine, the gas is injected into two places, the first place is into the intake manifold where the gas mixes with the air and is introduced into the cylinder during the intake stroke. The other injection place is the prechamber where the spark plug is located. Here, a richer mixture is injected which is ignited by the sparkplug. The ignition is transferred to the cylinder through holes in the prechamber.

There are two operating principles of a NG CI engine. The first one is the dual fuel (DF) engine which can run on NG or diesel. When the DF runs on gas, the gas is introduced during the intake stroke similarly to the SI process however, right before the end on the compression stroke a small amount of diesel, called pilot fuel, is injected into the cylinder, and works as the ignitor of the gas. The other type of CI engine is called gas diesel (GD) and enable the engine to run on either gas or diesel. The working principle is different to DF engine since the gas in injected after the compression stroke once the pilot fuel is already injected. Here, the mixture of high-pressure gas and pilot fuel ignites the fuel mixture.

2.2.2 Fuel conversion process

This section describes the fuel conversion process briefly as the process itself is very complex and going into detail is not the main reason for the literature review, rather give a general introduction to the process. Gas- and dual fuel engines are constructed in different ways compared to a diesel engine to enable the other type of operation (Kuiken 2016, p. 86 – 87). This means that several parts of the diesel engine need to be changed during the conversion process. The engine block and the driving gear components are often the same as the diesel engine for example, the same crankshaft, connecting rod and bearings can be used. The cylinder bores are often changed by using thinner cylinder liners or machining. They need to be larger since gas engines have lower cylinder pressures and the larger cylinder bores causes less force on the cylinder liners. Examples on this is the Wärtsilä 32 engine that have a 32cm cylinder bore that is changed to 34cm in their 34 SG and 34DF engines and MAN 48 diesel which cylinders become 51cm wide in their gas version. Naturally, the pistons need to be swapped to fit the larger cylinders, but they also need to be adjusted to achieve lower compression ratio since it restricts auto ignition of the gas. This is achieved by using pistons with lower height. Moreover, the material and piston rings are different than their diesel counterparts.

The fuel system of gas engines must also be modified (Kuiken 2016). In SI engines, spark plugs with their relative pre-chambers need to be added. The pre-chambers are necessary in larger gas engines that operates on very lean air-fuel ratios. In addition, ignition modules, ignition coils, extenders, electrical cables, etc. are added. Knock sensors are also needed to detect accidental ignition called knocking. Knocking can cause damage to the engine. The fuel supply system is also updated on the engine with specific fuel lines for the gas. Every cylinder has its own gas pipe from the main gas pipe. Furthermore, the cylinders are equipped with main gas valves and pre-chamber gas valves. The main gas valves determine the gas quantity to each cylinder and the gas to the prechambers are regulated by the pre-chamber valves. The gas systems must be designed with safety prioritized. Since NG is very flammable, even a small gas leak can have devastating results. For the gas valves to be controlled and the engine to successfully operate on gas the engine's control system also need to be upgraded (JFE 2014). Usually, the human machine interface (HMI) is either updated or swapped for a new version with gas features added (Martz 2012). The HMI is a system that enable the plant operator to control the engines and view engines sensor parameters and performance in one place.

When converting an engine to run on NG or DF not only components of the engine must be modified but also some of the systems and components of the power plant require modification (JFE 2014). The gas ramp or gas valve unit is one of the key auxiliary modules needed in the gas conversion of an engine (Kuiken 2016). The gas valve unit is responsible for delivering gas to the engine thus, it is positioned between the engine and the fuel tank. Naturally, the power plant needs fuel tanks or delivery systems and their accompanying delivery pipes to be added for the NG supply (Martz 2012). The gas valve unit's main components are shut-off valves, pressure regulators, filters, safety valves and ventilation valves (Kuiken 2016). The safety valves cut off the gas supply in case of an emergency stop or if the engine suddenly stops due to another problem. The function of the ventilation valves is to remove all possible gas that may remain in the exhaust system after the engines is stopped. The ventilation system is often equipped with a fan that removes all possible remaining gas of the exhaust system. This is of utmost importance to prevent explosions in the exhaust system or engine. The outlet of the main ventilation pipe must be outside of the engine hall and nowhere near possible ignition sources. The gas valve unit regulates the gas pressure however, after the gas valve unit the gas pressure is adjusted according to the engine load by the engine control system.

2.2.3 Fuel conversions in practice

There are very limited number of studies covering power plant engine fuel conversions. However, some studies on marine shipping engine fuel conversion can be found. Marine and power plant engine is often very similar or completely the same engine and can be used in both applications (Kuiken 2016). Totem Ocean Trailer Express (TOTE) Maritime converted two of their service ships to dual fuel operation and required a 90 million USD investment (Deal 2013). The price consisted of converting both ship's four MAN 9L 58/64 diesel engines and the complete replacement of two MAN 9L 28/32 diesel engines to more powerful MAN 9L35/44s dual fuel engines. These engines were replaced to make up for the 18% power reduction the conversion of the main engines resulted in, because the cylinder size was not increased. The research concluded that a bit over 80% of the project cost were associated with constructing the LNG tanks, fuel system and necessary safety equipment and only the remaining 20% where costs of converting the engines. The fuel system construction is especially expensive in marine applications due to very restricted spaces (Deal 2013). The fuel tanks themselves also take away otherwise usable space from the ship for example, for cargo since the LNG tanks are roughly twice as big as liquid fuel tanks. Naturally, in dual fuel conversions the diesel tanks cannot be fully removed either. The project estimated a payback period of ten years for the fuel conversion with the NG price of when the project was initiated in 2012. This is rather long as the expected lifecycle of the service ships is around 30 years. It was calculated that the fuel conversion project would be 15 – 40% cheaper than investing in completely new ships. The project opted to use the normal on-sea overhaul service to complete 30–40% of the conversion and the rest, mainly installation of LNG tanks, had to be done while at drydock. This draws similarities to the proposed success factors of retrofits in Sanvido & Riggs (1993).

Antunes et al. (2012) converted two Wärtsilä 9L32 diesel engines in marine application to become dual fuel engines running mostly on NG but having the possibility to run on heavy fuel oil (HFO) as well. The commissioning of the engines was done in December of 2008. The post conversion performance test showed comparable performance to HFO when running on NG. The research found the need for knock detection sensors and engine control to manage injection because of faster pressure rise and cylinder peak pressure when running on NG. To avoid knocking the engine was set to operate on 70% NG and 30% HFO which does not resemble the mix between NG and diesel of modern dual fuel engines which is around 1 – 10% diesel and 90 – 99% NG (Kuiken 2016, p.17). However, with this fuel mix the emission analyses showed a 16% reduction of CO_2, 50% reduction of particulate matter and NOx emissions reduced 10% compared to HFO operation on the same load (Antunes et al. 2012). The researchers estimated a payback time of less than a year for this application and was calculated by the price of NG and HFO in 2008 and the achieved engine performance. This is significantly less than the project in Deal (2013) however, the initial investment of this conversion was not disclosed in the research.

Efekas et al. (2020) investigated the environmental and economic benefits of converting a large container ship's (A7 class) low speed marine diesel engine Wärtsilä 11RT-flex96C to dual fuel operation. The container ship's fuel costs were estimated to 16,03 million US $ when run on diesel and once converted to dual fuel 11,27 million US $. Thus, resulting in fuel savings of 4,77 million US$ or roughly 30% every year. In addition, the savings in maintenance costs due to the conversion where also calculated and concluded to 480 841 US$ annually. With the combination of these and approximating a 2% fuel cost increase the total savings of the fuel conversion is 22,42 million US$ over the remaining of the ship's lifecycle. In a similar study, but for high-speed marine engines, the costs benefit of dual fuel conversion was a decrease of 39% in fuel costs and 40 percent in maintenance costs (Banawan et al. 2010).

Although these studies' results show promising reduction of operational costs, they cannot be directly compared to the reduction of operational costs of engine power plants. There are very limited studies on the economic advantages of fuel conversion of engines in power plant applications which indicates a large research gap. However, by comparing new build NG engine power plants to diesel engine power plants a sense of the economical differences can be formed. When diesel engine power plants generate electricity for baseload use, they have a power generation cost of around 197 US$/MWh and when generating electricity for peak demand or emergency use the costs are around 281 US$/MWh (Lazard 2017). Comparing this to NG engine power plants the respective costs are 68 US$/MWh and 106 US$/MWh which is significantly less. To be noted, these are calculations based on the NG price in USA at the time of the study.

Similar financial benefits were found in the feasibility study conducted in 2013 by Stornoway Diamond Corporation comparing the costs of a diesel engine power plant and an LNG power plant (Stornoway Diamond 2013). The study concluded that by choosing LNG as fuel the operating costs would be 37% less. The operating costs were calculated as 0,299 $/kWh for diesel and 0,188 $/kWh for LNG. This would result in 8–10 million dollars in operating costs savings every year for the plant. The initial investment of the plant would be only 2,6 million dollars more which would pay itself back in 4 months more compared to the diesel alternative.

Based on the concluded environmental benefits of fuel conversion of diesel engines in the marine sector (Elkafas et al. 2020; Antunes et al. 2012; Banawan et al. 2010) and the financial benefits (Antunes et al. 2012; Deal 2013; Lazard 2017; Stornoway Diamond 2013) the literature create a strong case for performing fuel conversion from diesel to NG. The combination of achieving reduced emissions and operating costs is tempting reasons for implementing a retrofit of an existing engine power plant. Unfortunately, there is a rather large gap in the research for fuel conversions of ICE powerplants. Properly conducted research with hard results of benefits and challenges of ICE power plant fuel conversion from performance, environmental and financial viewpoint could urge more actors in the energy sector to invest in retrofits. Therefore, research on the execution and project management of retrofit projects could be beneficial as well, something that was also noted in Fox (2003).

2.3 Knowledge transfer as part of knowledge management

To understand knowledge transfer, it is good to define what knowledge is to begin with. Defining knowledge is not the easiest task as there are many definitions depending on which standpoint knowledge is analyzed from. For instance, according to Nissen (2002), knowledge is derived from information which in turn is created from data. Data is used to create information by giving it a suitable context. Further, when information is usable in practice it develops into knowledge. Some researchers suggest that knowledge is only a domain of people’s minds and is transformed to information when it becomes an exchangeable form for example, a document or book (Al-Hawamdeh 2002; Davenport & Prusak 1998; North & Kumata 2014). Knowledge is information that has been made stronger from the experience of the individual possessing the knowledge. North & Kumata (2014) argues that the knowledge is bound to the person knowing it and thus, there is seldom a way of accessing it because the knowledge cannot be shared without the person acquiring it. The researcher presents an example of a painter describing his painting, although the painter would describe the painting process in detail it could not be recreated perfectly by another painter. This example describes knowledge in an understandable way. Even with the information of a certain task it may not be reproduced accurately without the experience of doing the task beforehand.

Knowledge can be divided into two different forms, explicit and tacit knowledge (North & Kumata 2014). Explicit knowledge is knowledge that can be made tangible, and that way be shared with others. It often has specific structure and made more formal to be presentable. Explicit knowledge can be for example manuals, practices, or documents (Bower & Walker 2007). On the other hand, tacit knowledge is the knowledge that is in more vague form and hard to conceptualize, often existing only in the mind of a person. Tacit knowledge is derived from previous events such as projects, lessons learned, and other experiences from situations that has arisen from the execution of these events (North & Kumata 2014). Furthermore, factors like education, values and emotions play a role in the formation of tacit knowledge. This knowledge form is exactly what the department members at the case company possess and must be transferred throughout the department.

Knowledge management is the practice of gathering, sharing, and using knowledge in a structured and defined way between individuals, teams, and departments throughout an organization (North & Kumata 2014). The objective of knowledge management is to effectively use the knowledge of an organization to support the pursuit of the strategic and operational goals of the organization. Effective knowledge management transforms an organization’s data and information to knowledge which enables greater competitive advantage, which in turn can benefit project or business success (North & Kumata 2014; Yap et al. 2021).

Knowledge transfer is an essential part of knowledge management (Davenport & Prusak 1998). Knowledge transfer is a process of knowledge management where knowledge is shared between counterparts. There are two sides when transferring knowledge, the providing end and the receiving end. The providing end provides knowledge to the receiving end which occupy the knowledge. Knowledge is considered successfully transferred only if the receiving end can comprehend and use the knowledge effectively. This implicates that sharing knowledge in any form is not enough since the aim is to make the knowledge understandable and presentable to a counterpart who can comprehend and use it in the future. Therefore, knowledge transfer itself does not bring value if the receiving end cannot develop its knowledge further with the provided information.

In theory, knowledge transfer does not need any governance to happen since knowledge is continuously shared by collaboration between individuals in organizations (Davenport & Prusak 1998). This unstructured knowledge sharing is also the most common form of knowledge transfer and is present daily in organizations for example, when employees talk to each other, in meetings and in joint problem solving. However, this form of knowledge transfer mostly transfers tacit knowledge. For explicit knowledge other forms of sharing can be used for example, through documents, manuals, and notes. Therefore, a company can increase benefits by implementing a knowledge transfer strategy or system that incorporates both tacit and explicit knowledge transfer.

Nonaka & Takeuchi (1995) introduces a concept of four alternative knowledge transfer scenarios, socialization, externalization, internalization, and combination. These scenarios represent the different combinations of tacit and explicit knowledge sharing and is illustrated in figure 1.

Tacit to tacit (Socialization)	Tacit to explicit (Externalization)
Explicit to tacit (Internalization)	**Explicit to explicit** (Combination)

Figure 1. Four types of knowledge transfer (Nonaka & Takeuchi 1995)

In the socialization scenario tacit knowledge is exchanged with tacit knowledge. In this process experience is shared and the knowledge is transferred through conversation, observation, imitation, and practice. Tacit knowledge can also be transferred to explicit knowledge by objectifying it for example, by writing it down in a document. This process is called externalization. Internalization is the process of transforming explicit knowledge to tacit and is often realized when an individual view content such as, documentation, frameworks, or models and can use this knowledge to broaden their knowledge. The common phrase "learning by doing" is an excellent example on internalization. Finally, when explicit knowledge is exchanged with explicit knowledge it is called combination. This type represents codified knowledge being analyzed and new connections between the knowledge is formed. The codified knowledge can be sorted, developed, and reconfigured and thus, new knowledge is created.

According to North & Kumata (2014), effective knowledge transfer can be enhanced by having a good foundation for sharing the knowledge. This foundation should consider the organizations values and principles as well as the vision and mission of the company for the knowledge transfer to support these. The organizations processes must be optimized for knowledge creation and transfer. The organization should create a system that enables the flow of knowledge to the ones in need of knowledge which is given by people who have the required knowledge. The researchers describe this concept with the metaphor *knowledge market* where there is a supply and demand of knowledge. The market could be as simple as a conversion group on intranet where questions can be asked and is answered by more experienced employees.

2.3.1 Knowledge transfer in project environments

Spalek (2014a; 2014b) found that knowledge management is considered a key success factor in project success, and its significance is highlighted in project-based organizations. The result of the research is based on quantitative data from 447 companies. By creating an organized way of transferring knowledge to where it is needed and using the knowledge effectively, an organization can increase project performance. This can lead to increased project quality and reducing the lead time and budget. There is focus on creating and maintaining a structured data repository for storing codified knowledge. The research concluded that companies often struggle to find a defined way of transferring knowledge and there is lack of encouragement to share knowledge throughout the company. This results in the employees avoiding transferring tacit knowledge to explicit without developing documentation and adding this to data repositories since they do not understand the importance of it. As a result, the company's data repository is rendered useless since it is either containing too little information or filled with wrong kinds of information. The research also showed that there is a significant lack of knowledge management maturity in the companies' project management.

In larger project-based organizations which has more than 50 employees it is recommended to incorporate a project management office (PMO) which should govern the knowledge transfer in and between projects (Spalek 2014b). The PMO should be responsible of creating and controlling the data repository and encouraging the knowledge transfer on both individual, project and organizational level. The PMO is also responsible of providing the organization external knowledge which is outside of the organization for example training, information packages or standards. In a study conducted by the researcher, 272 of over 400 interviewed companies had a PMO in use and of these 46% were assigned knowledge transfer as their responsibility. In another study 403 PMOs were studied and nearly 38% of these highlighted the importance of facilitating a data repository.

Disterer (2002) recognizes similar challenges of knowledge transfer. There is a significant lack of knowledge transfer between projects in the end of a project's lifecycle. The project organization is often dissolved for the members to be assigned new projects and in this process, there is a lack of interest and encouragement in mapping out the experiences gained during the past project. There is focus on finishing project documentation, but this is often product and development documentation which does seldom contain knowledge valuable for the upcoming projects. The research emphasizes the importance of lessons learned style documentation where the project teams experiences, problems and their solutions, pitfalls, success stories and more would be documented.

Disterer (2002) also implies the use of databases for the storage of knowledge documentation such as lessons learned, and these should work like knowledge banks like the knowledge markets presented by North & Kumata (2014). Here, individuals could easily search for knowledge for example, solutions to a problem by using keywords. However, it is also recommended to keep lists of experts in the database from who specific questions can be asked enabling tacit to tacit transfer. Not only current employees benefit from the knowledge database, but also new employees can gain great amounts of knowledge of past projects making them integrate faster.

According to Disterer (2002) there should be focus on how the knowledge of a new project will be transferred already in the project's initiation phase. This means that the project organization understands there will be reflection sessions in the end of the project and thus, experiences should be documented throughout the project on the individual plane. The research presents another useful knowledge transfer tool in form of interviewing experienced project members in the beginning of a project for a new project organization to gain knowledge from similar projects from the past.

According to Yap et al. (2021), lack of appropriate project knowledge results in missing a project's time and budget targets in large amounts of projects in the construction sector. Through the study's explanatory factor analysis, six factors related to knowledge are ruled out as reason behind the project failures. These factors are incorrect estimation of resources, changes in design, lack of resources, not enough experience nor competence, and mistakes. The research also present benefits of incorporating knowledge management with project management. Combining the two can result in greater project success and gain competitive advantage by creating and sharing knowledge from project experience, reuse solutions for problems, and gain ways of working from other people and projects. Furthermore, the combination may encourage greater collaboration within the organization which in turn lower the risk of unsuccessful projects.

Wiewiora et al. (2010) studies the knowledge transfer inside project teams and between different project teams. The research found that knowledge transfer inside the project team was much more common than transfer between project teams. However, in organizations where individuals are assigned to several projects simultaneously knowledge transfer between teams were apparent. The research indicated that the people working on multiple projects is not enough for effective knowledge transfer and should foster knowledge transfer through social gatherings such as workshops or knowledge building meetings. It is also recommended to enable transfer of explicit knowledge by incorporating knowledge repositories, drawing similarities to Disterer (2002), North & Kumata (2014) and Spalek (2014b). Here, there was similar emphasis on the need of the databases or knowledge repositories to be organized and simple to enable finding information quick and easy. The projects studied in the research favored transferring knowledge through social interaction rather than using technical tools. This shows that project members rather ask each other of possible problems rather than turning to documents or manuals for help. There was also indication that some amount of knowledge is transferred through e-mail.

The literature on knowledge transfer indicates that there are indeed many different styles of transferring knowledge (Nonaka & Takeuchi 1995). However, it is not ruled out what is the most efficient way of knowledge transfer. This thesis will explore if knowledge of a subject, in this case fuel conversion, can be transferred in concluded form with the help of a framework. The literature suggested the use of repositories and knowledge markets for storing and sharing knowledge (Disterer 2002; North & Kumata 2014; Spalek 2014b; Wiewiora et al. 2010). This research will address if a project management framework could be used as both a knowledge market and a database for storing fuel conversion specific knowledge.

2.4 Project management frameworks

2.4.1 Frameworks vs Methodologies

The terms project management framework (PMF) and project management methodology are rather confusing and different research use the terms interchangeably or the hierarchy of the terms are unclear. However, there is a notable difference in the definition and in practice (Cohen 2016). Kerzner (2010, p.99) defines a methodology as following, ”a methodology is a series of processes, activities, and tools that are part of a specific discipline, such as project management, and designed to accomplish a specific objective”. Methodologies are more formal and structured with stricter processes and guidelines which should be followed precisely. Organizations adopt or develop a PM methodology to streamline their PM process when their projects are consistent, and the project outcome is similar in between the organization’s projects. The objective of a methodology is to provide guidelines and direction for the project process and support the project manager in decision making. Organizations tend to incorporate a PM methodology as a first step towards so called project management excellence.

When the organization’s PM maturity increases, the PM methodology’s processes are modified towards more informal tools and activities such as templates, checklists, and documents (Kerzner 2010, p. 99). As a result, a project management framework is born and is centered around the more informal attributes. As stated in the introduction a PM framework can be adopted with more flexibility and provide the possibility to be tailored more freely to project requirements. According to Kerzner (2010, p.99), a framework can be defined as, *A basic conceptual structure that is used to address an issue, such as a project. It includes a set of assumptions, concepts, values, and processes that provide the project manager with a means for viewing what is needed to satisfy a customer's requirements. A framework is a skeleton support structure for building the project's deliverables.*

Generally, frameworks are not linked to a particular industry while methodologies usually are (Garton & McCulloch 2012). There are multiple renowned PM methodologies and frameworks in use, but the organizations can also develop their own to fit their requirements. According to Shenhar et al. (2015), organizations should opt for developing frameworks for different project types and not try to utilize so called one-size fit all frameworks.

Tonnquist & Holmén (2018) introduce an alternative name for a PM framework called project model. A project model's objective is to describe how the project *is to be done* while a PM methodology's aim is to determine how the project management *should be done*. A project model is created for project governance and management and is there to support the adoption of a PM methodology. Project models can also be developed inside the organization for their projects. Figure 2. shows an adapted figure of Tonnquist & Holmén (2018) hierarchy of standards, project models, methodologies, and tools.

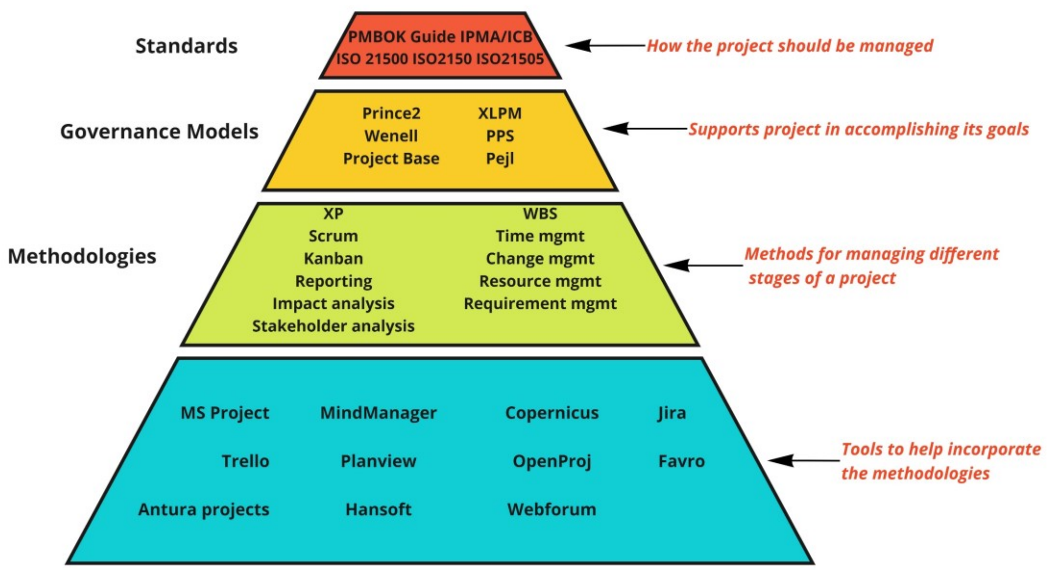

Figure 2. Hierarchy of standards, project models, methodologies, and tools (adapted from Tonnquist 2018, p. 472)

Garton & McCulloch (2012) state a parallel between PM standards and process frameworks. Examples of well-known standards are Six Sigma, International Organization for Standardization (ISO) standards and Project Management Institute's (PMI) Project management book of knowledge PMBOK Guide. Process frameworks are like standards and are frameworks that can be applied to existing methodologies to support the use of the methodology. An example of process framework is PRINCE2. Process frameworks can be used in various industries and types of projects. The process frameworks cannot substitute the methodology itself but work as a roadmap for the adoption of its respective methodology. It does not replace project management competence either, meaning an unqualified project manager cannot become sufficient in project management using the framework but can use it as a helping hand. The definition of a process framework is like Tonnquist & Holmén (2018) definition of the project model. This is further emphasized in the fact that Garton & McCulloch (2012) determine PRINCE2 as a process framework and Tonnquist & Holmén (2018) as a project model.

There are advantages and challenges of both PM methodologies and frameworks (Kerzner 2010). PM Methodologies are great for large project-based organizations running multiple similar projects. The methodology provides a unified way of working for the projects which generally makes PM more effective, and the project team has plenty of tools to work with. However, the adoption of a PM methodology requires a lot of effort from the organization because there is need for training in using the methodology. Furthermore, sometimes the project team put too much time into trying to follow the methodology that it takes time away from the project work itself. The process of a methodology is often defined and viewed as mandatory and makes the methodology inflexible. The benefit of frameworks is that they are structured in a way that can be followed how the user sees it necessary and utilized either strictly or more freely. In addition, the framework can be tweaked to fit the personal way of working of a team member but also used differently depending on the project requirements. This results in frameworks being easier to pick up and require less effort by the organization or project team. However, a framework can be hard to follow if the project's requirements a complicated and puts too much pressure on the project team.

A challenge with frameworks is that there is a tendency that developed frameworks end up by not being used by various reasons (Tonnquist 2012). Usually only the individuals involved in the development of the framework end up using it. The biggest reason the implementation of a framework fail is that it is far too complex and difficult to use. A framework needs to be marketed internally and have the support of top management to be established as a way of working. Furthermore, an important aspect is that every intended user of the framework must know of its existence. A random sample of Stockholm based companies from different industries show that 37% of the companies use a PMF, 15% has developed their own PMF, and 48% do not use any PMF. A commonality of the respondents was that the PMF was not utilized regularly after its development.

Currently there are many publicly available PMFs that have been developed for both specific industries and there are more general ones to be applied to multiple industries (Garton & McCulloch 2012, p. 39). Tonnquist & Holmén (2018) argues that the available PMFs are quite similar in their structure and the biggest difference is in the terminology used. When reviewing literature about available PMFs there seems to be confusion regarding which are considered frameworks and which are methodologies and as mentioned earlier some researchers put PMFs and standards under one term (Garton & McCulloch 2012, p. 52).

2.4.2 Development of project management frameworks

PMFs can be developed in different ways but there are similarities in the proposed types (Cohen 2019; Conley 2016; Naybour 2014). When building a PMF from scratch for the companies projects it is great practice to evaluate existing PMFs and utilize these for the framework rather than waste resources on developing identical frameworks (Cohen 2019). The first step of developing a PMF is to evaluate the project process and gather information of each phase of the project lifecycle and what goes into these (Cohen 2019; Conley 2016; Naybour 2014; Tonnquist & Holmén 2018). The relative information required for the development of the PMF can be collected by interviewing project teams and mangers to gain insight on what is needed for the execution of the project and meeting the requirements (Conley 2016). Customers can also be interviewed to understand their perspective on a successful project and PM. The project's problems can be studied further to form new ideas of solutions, technologies, and trends. This information creates the building blocks of the framework so there should be effort put into the pre-study.

The next step is dividing the framework into relative categories based on the gathered information (Conley 2016). The categories can be different requirements of the project or processes. The project can also be divided into different stages representing each phase of the project life cycle (Naybour 2014). This is very common in many of the commercially available PMFs as they utilize stage-gate models (Tonnquist & Holmén 2018; Garton & McCulloch 2012). The categorization creates structure into the framework and help in the visualization of the framework (Conley 2016). A framework can be visualized as simple as a table if the complexity of the PMF allows where the categories are listed in columns and the respective cells describe the process of the categories. However, if the project is more complex it can be visualized in more comprehensive and appealing ways using diagrams, timelines, process maps or similar. A PMF can consist of only visualizations however, some documentation or description of the PMF is generally a great idea to better describe the different parts of the project. Duggan & O'Neill (2013) recognized that the descriptive documentation, which included polices, practices, and standards of the PMF, might have added to the expenses of the development of the PMF in the study but it created an important ensemble of visualizations and documentation.

In good performing PMFs the project's responsibilities are assigned to different roles (Tonnquist & Holmén 2018; Naybour 2014). The framework should state the project's different processes, activities, and responsibilities to respective roles. A PMF for large-scale projects should at least define the following roles and the roles' responsibilities, project board, project executive, project manager, and project team (Naybour 2014). In addition, the PM rules of the framework need to be established (Cohen 2019). The rules support the PMF to create consistency throughout projects by determining how the projects will be executed and how the information they create will be handled. For example, guidelines of knowledge sharing prevent the lessons learned of a project to stay only within the project team. Other example of rules that should be defined are documentation guidelines, who has access to documentation, which templates should be used, financial reporting, in which projects the PMF will be used, how the resources are allocated, ways of communication etc. If a stage-gate process is utilized the documentation and templates for each stage should be defined in the framework (Naybour 2014). To be remembered, the templates should be tested in projects with key stakeholders involved to ensure they are functional. Tonnquist & Holmén (2018) also realizes the determination of the templates and checklist as one of the three key aspects of a PMF.

After these steps at least a first version of a framework should be completed. Before the framework can be taken into use it must be tested and evaluated (Naybour 2014). A crucial evaluation is to determine the PMF's fitness to the organizations other processes. The PMF should align with the organizations or departments other core processes such as business planning, engineering, and supply chains. The PMF is quite useless if it cannot work with the other processes. It is important to involve the project stakeholders in the development of the PMF since something that is being developed in the background without others involvement is doomed to fail or will not be adopted resulting in plenty of resources lost. A newly developed framework should also be presented to its users and training of the usage of the framework is also at its place because it can present new processes and tools unfamiliar to the organization.

According to Tonnquist & Holmén (2018) a framework should be developed to be light and flexible since a complicated framework impose challenges in time, usage, and restricts freedom of implementation. However, if the framework is too simple, project members will start working as they see necessary since the framework does not guide them enough. Generally, it is not a great idea to develop a framework off only one successful project since it could have been a success only due to special circumstances, the framework should rather be developed of best practices of several projects (Tonnquist 2012). Good practice in framework development is to begin with a simple version and expanding it gradually according to new requirements (Tonnquist 2012; Naybour 2014). The more the framework is used the number of improvements noticed increases. The probability that a PMF performing well in the first version is low and will probably need improvement during its use. A framework also needs a moderator who is responsible of updating the framework and offer training.

Duggan and O'Neill (2013) agree on several of the best practices in developing PMFs with Tonnquist & Holmén (2018), Naybour (2014), and Tonnqvist (2012). The main similarities are the importance of keeping the PMF as flexible as possible, ensuring the end users' involvement in the development of the PMF, and the support from top management. However, the research also points out other crucial principles of the development. They emphasize the importance of using change management, as the challenge is not only in developing the PMF but also introducing the framework for the organization without creating resistance to change. It was mentioned earlier that implementation of a PMF will cause change thus, the research claims that proper change management is a crucial factor in the success of the PMF. It is helpful to present the areas where the PMF will bring benefits to the stakeholders. This helps the stakeholders to understand why the PMF should be implemented and why change is necessary.

Trentim (2020), presents a simple structure which can help in developing a PM methodology specifically for the projects of an organization. The structure is based on a table which columns represent the process groups of a project. The first row state each process group's objectives. The second row presents the key outputs of the process groups. The structure support in finding what is important in each phase of a project. An illustration of the table is found in figure 3.

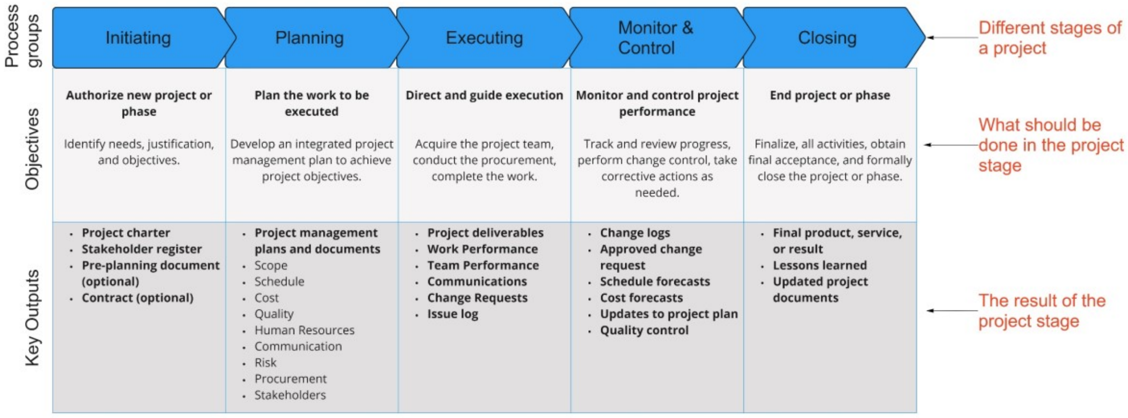

Figure 3. Illustration of a structure to support the development of a PM methodology for an organization's projects (adapted from Trentim 2020).

2.4.3 Project Management Framework Research

Some studies can be found where frameworks have been developed for different purposes in project management. Shenhar et al. (2015) developed a PMF for NASA to help them divide their projects by their type and manage them accordingly. NASA realized that they managed all their projects in the same way although there were differences in the style of project. Additionally, they lacked guidelines for management of the different project types. Furthermore, while they had studied different options for frameworks for the characterization of different projects, they had not managed to find one suitable to their needs. To successfully develop a PMF as accurately as possible the researchers implemented the case study method. They studied four projects each of different nature comprehensively by interviewing the project members, project manager, top management, customers, and sub-contractors. The interviews were conducted using a structured interview guide developed to map out project structure, project processes, project organization and project evaluation metrics. In addition, project documentation, templates and plans of each project were analyzed.

The developed framework was an early version of a framework which could be elaborated further when it has matured (Shenhar et al. 2015). The framework used the NCTP model developed in Shenhar and Dvir (2004) also known as the diamond model and

NASA's existing classification framework as a foundation. The NCTP model can be used to classify a project based on four factors, novelty, complexity, technology, and pace. Based on the analysis the right management style can be implemented. Each factor has different dimensions which describe the level of the factor the project is on. The NCTP model can be viewed in figure 4. Moreover, NASA's classification framework focused on the type of products used, priority, life-cycle costs, technology readiness, project leadership, and level of risk.

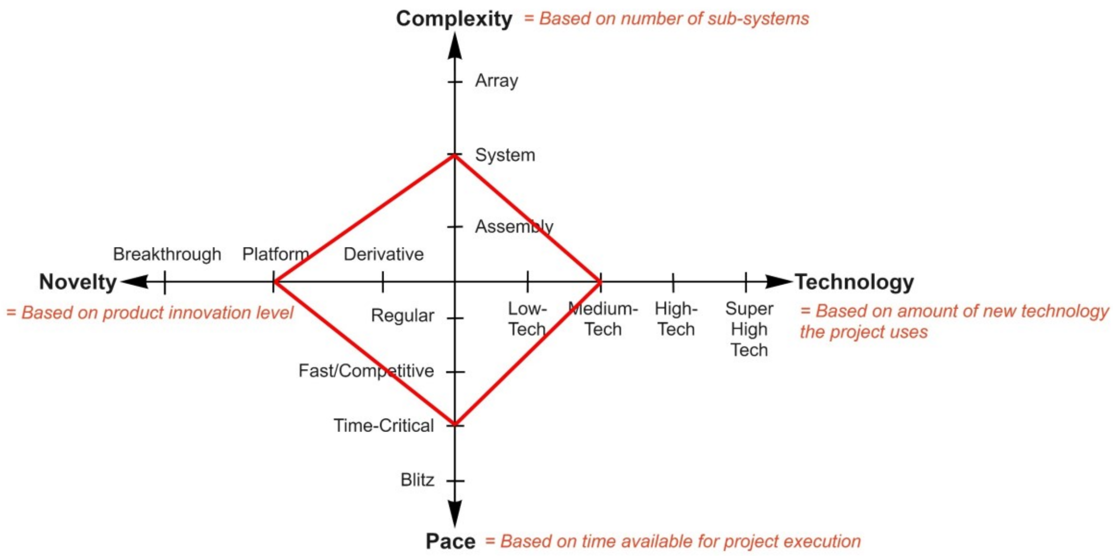

Figure 4. Illustration of the NCTP Model (adapted from Shenhar et al. 2015).

Based on the NCTP model, NASA's existing framework, and the case study a new PMF framework for classification was developed. The result was a framework visualized in table form where the project characteristics were listed in one column, project type in the following column, and the third column would describe the impact on PM style. Each row would classify the project according to the characteristic and the belonging project type. Although this PMF was focused more on classification of project type and how it would impact the PM, the development of the framework is relevant to this research. This research used a similar research method to Shenhar et al. (2015). A table illustrating the framework visualization can be viewed in table 1.

Category	Possible Project Types (i.e., characteristics)	Impact on PM style
Mission	Science, Exploration, Space operations, Aeronautics	*Here the effect on project management style would be described for each category.*
Flight	Manned, Non-manned, Payload	
Owner	PI-Led, Non PI-led	
Risk class	A-D	
Novelty	Derivative, Platform, Breakthrough	
Complexity	Assembly, System, Array	
Technology	Low-tech, Medium-tech, High-tech, Super High-tech	
Pace	Regular, Fast/Competitive, Time-Critical, Blitz	

Table 1. Framework to determine how NASA's PM will be implemented according to the project type (adapted from Shenhar et al. 2015).

Duggan & O'Neill (2013) describe the development and implementation of a PMF used throughout the whole organization, a so-called corporate project management framework. The organization itself was the city of Calgary which run many different projects through many departments in various fields such as transportation, utilities, buildings, and so on. After an audit of the PM of the organization, it was found that there was a need for unified PM principles as at that moment the organization did not follow whole heartedly the PM guidelines established earlier since their use was stated as optional. The aim for the framework was to, "support the delivery of project results consistently, effectively, and efficiently". and would bring benefits in cost management, risk management, transparency, and greater support for project managers.

The PMF development began by creating a conceptual model of what the PMF would become (Duggan & O'Neill 2013). The conceptual model worked as a first version of the framework and gave a basic structure of the PMF which in turn, helped in determining what would be included and who were responsible of each part. The framework is structured in three levels representing the PMF goal on top, the required PM components of the PMF in the middle and the inputs for the components on the third level. As mentioned earlier, the PMF consist of both the illustration of the framework and a document which describes the framework and its components in detail. The visualization of the framework can be viewed in figure 6.

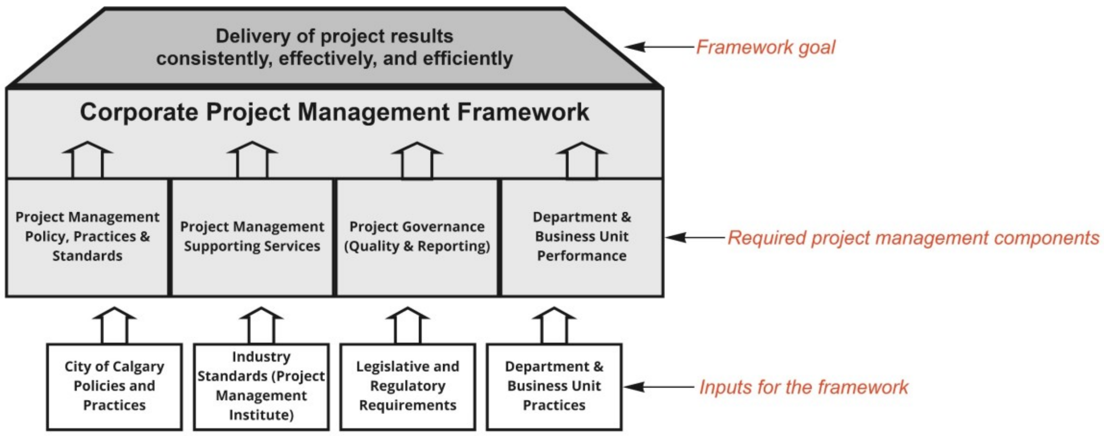

Figure 5. Illustration of corporate PMF conceptual model (adapted from Duggan & O'Neill 2013).

As can be seen from the framework visualization, the framework used processes that the organization used previously in combination with existing industry standards similarly to the suggestion mentioned by Cohen (2019). The practice of starting out with a conceptual model or simple first version links the PMF to Tonnquist (2012) and Naybour (2014). Furthermore, the development of the corporate PMF included creating standards for PM for each department (transportation, building, etc.). The objectives of the standards were to dive deeper into detail of PM principles for each department and define the PM deliverables. The standards were developed by gathering key stakeholders from each department into teams who were responsible of developing the standard. The aim for the development team was to focus on what is required to be done in the project and not on how it will be achieved to keep the standards flexible and thus, the framework light and adaptable. These principles connect to the theory of flexible frameworks (Tonnquist & Holmén 2018) and the importance of involving key stakeholders (Naybour 2014).

The literature shows that there is quite much confusion of what is considered a PMF and what a PM methodology. Furthermore, there is different terminology for similar definitions of PMFs. Fox (2003) suggested that retrofit projects should have retrofit specific methodologies. However, the available PMFs and PM methodologies developed for commercial use are more for general project management. In this thesis a PMF is developed for a project type at the case company, to support the execution of these projects and resolve challenges that these projects are susceptible to. Therefore, the developed PMF is retrofit specific to be applicable to the characteristics of the fuel conversion project type. A future research topic could be to develop a general retrofit PM framework or methodology to be used for any style of retrofit project.

3 Research Methodology

This chapter presents the research methodology and discusses the choice of method for the research. The chapter also present the research approach, data collection strategy and how the data is analyzed. Finally, the strategies for ensuring adequate research quality are presented and discussed.

3.1 Research design

For the research design of this thesis the qualitative research design was chosen. Today qualitative research acts like an umbrella term for many different styles of research which share qualitative characteristics and therefore, has many definitions (Hennink et al. 2020, p. 10). Savin-Badin and Major (2013) define qualitative research as "Social research that is aimed at investigating the way in which people make sense of their ideas and experiences." Qualitative research is utilized when the experiences and knowledge of individuals are used to form an idea or point of view of a particular problem or phenomenon. In essence, the researcher of a qualitative study must understand the research participants' perspective of the problem and by combining the views, form a conclusion (Hennink et al. 2020, p. 10). The experiences of individuals can be captured using different tools for example, interviews, discussions, observations, and content analysis to name a few.

To have the required foundation of the fuel conversion projects to build the PMF upon, there had to be comprehensive understanding of the project type. As stated earlier, the knowledge of the project type is currently acquired by the department members that have performed fuel conversion projects previously. Therefore, as the literature indicated, the experiences of these individuals could be used to form an understanding of the project type (Hennink et al. 2020; Savin-Badin & Major 2013). Moreover, the tools for data collection used in qualitative research suited the research well because interviews were not the only data collection method, but observations of lessons learned sessions and analysis of case company documents was used as well. Therefore, the qualitative research design was considered appropriate for the research requirements.

3.2 Research method

The case study was chosen as research method in the research. Yin (2003, p. 13) defines case study research as following, “A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context”. Case study research can help in developing a picture of a distinct topic and is especially applicable when comprehensive research is needed (Zainal 2007). Case study research is flexible and enable the researcher to investigate a topic from different goals, viewpoints, and research approaches (Savin-Badin & Major 2013). Case studies create thoroughness by focusing on a smaller number of events but understanding these more completely instead. Their focus tends to be more specific and is appropriately limited to the research objective. Case studies allow the possibility to use several styles of data collection, both qualitative and quantitative. This supports thoroughness of the research and provides flexibility in the research strategy. Case study research is also responsive since it is not restricted by time or approach. Furthermore, it is great for explaining and documenting a phenomenon while it is happening. These are the key advantages of case study research.

There are different kinds of case studies depending on what purpose and objective the research has (Savin-Badin & Major 2013). This study utilized the exploratory case study. Exploratory case studies may be used to introduce new topics to study or be a pre-study for a larger research project. In exploratory case studies the research might collect data before defining research questions to find the best topics to study (Yin 2003). However, exploratory case studies are mainly used to answer research questions structured by what based questions. This thesis’ research questions were structured by both what and how. These factors indicated that the exploratory case study was an applicable research method.

Regardless of which type of case study is chosen the unit of analysis must be decided (Yin 2003, p. 23–24). The definition of unit of analysis is quite self-explanatory, it is the focus point of what is being researched. In case study research it forms the case. The research questions of the study should form a unit of analysis and if your research questions cannot satisfy one unit they are not defined clearly enough. In this research the unit of analysis was the fuel conversion project.

According to the literature the case study approach supported the goal of the research, to study the fuel conversion project type and to understand it as holistically as possible to help create the PMF (Savin-Badin & Major 2013; Zainal 2007; Yin 2003). Savin-Badin & Major (2013) stated that case study research is very suitable when trying to solve a particular problem. In this research the PMF was intended to offer a solution to support the case department in executing fuel conversion projects. Furthermore, the possibility to use several data collection methods was important to have enough data of fuel conversion projects. The above and previously mentioned factors conclude that the case study research method was a suitable method for the research.

3.3 Data Collection

According to Yin (2003, p. 97), the preferable way to implement case studies is to use multiple sources of information. One of the main advantages of case studies is the ability to use multiple information sources. By using multiple sources, the research generates more compelling results. This subchapter describes what data collection methods were used in the research and how they were utilized.

3.3.1 Semi-structured interviews

The main method to collect data for the research was semi-structured interviews. Semi-structured interviews are characterized by a set of main questions which create a foundational structure for an interview (Gill et al. 2008). However, the interview is not bound to these questions only, which would be the case for structured interviews (Bryman

2012). Semi-structured interviews allow modification of questions during the interview and the use of additional questions that may arise following the answers to the main questions. This makes semi-structured interviews flexible and enable comprehensive answers to the questions. Generally, questions called probes are used to support the interviewed person to find answers and stay on topic.

Since the department members that have worked with fuel conversion projects had the required knowledge how to execute them, they were the most important source of information for the PMF. Therefore, the key department members were interviewed to transfer their knowledge through the PMF to the rest of the department. The interviewees, here after called respondents, were chosen based on the experience they had with fuel conversion projects. The respondents were handpicked by the department manager since they had the best insight of who had appropriate experience. Five respondents were chosen by the department manager which resulted in five interviews held. The respondents were three project managers and two project engineers with varying seniority. This followed the purposive sampling strategy where interviewees are chosen distinctively because it is believed that they have valuable insight to the case rather than choosing random individuals (Robinson 2014). By interviewing not only project managers but also project engineers, variety in the answers was created as several perspectives on fuel conversion projects were included in the data collection. Table 1 provides additional information about the interview process.

Participant	Role in project management team	Years of working at case company	Interview date	Duration (min)
Respondent 1	Senior Chief Project Engineer	15	21.12.2021	55
Respondent 2	Chief Project Engineer	13	11.01.2022	63
Respondent 3	Project Manager	17	12.01.2022	54
Respondent 4	Project Manager	9	14.01.2022	72
Respondent 5	Senior Project Manager	24	24.01.2022	100

Table 2. Participants in the interviews, their role, years of experience at the case company, and interview date and duration.

The interviews were held remotely because of the Covid-19 virus situation still making organizations recommend remote work. Prior to the interviews the respondents got introduced to the purpose of the research by their manager. The respondents were invited through an email that also stated the purpose and process of the interview. The software used for the video conferences was Microsoft Teams. English was the language of the interviews. The interviews were recorded to enable the researcher to focus better on the conversation and engage more freely in the interview. The recording also helped the transcribing of the interviews.

The interviews were transcribed as soon as possible after completing them. The interviews were transcribed using non-verbatim transcription method. Using this method, the researcher converts the spoken sentences to text as they are but excludes unnecessary pauses, throat clearing, filler expressions, etc. (Brooks 2021). Therefore, some words such as "uhm", "of course", and "also" were left out in instances where they were repetitive. However, the original structure of the sentences was kept. Non-verbatim transcription was used to keep the original authenticity of the interview while making the transcriptions easier to analyze.

3.3.2 Case company documents

The second type of data collection used was documents provided by the case company. The documents used in the data collection was an introduction to fuel conversion projects, lessons learned power point presentations of previous fuel conversion projects, and a document describing the case company PM model. Analysis of documents allow studying different sources of written documents such as articles, books, newspapers, or journals (Morgan 2022). Documents can be used in data collection as they can reflect thoughts and opinions like those present in interviews and observations (Merriam & Tisdell 2016). By using documents in combination with interviews and or observations, triangulation can be achieved (Bowen 2009). Triangulation is the use of different sources to ensure greater credibility throughout the research (Tracy 2010).

The document of biggest value for the PMF was the introduction to fuel conversion projects document developed by one of the case company's project managers. The document describes the main purpose of the projects and goes through the project scope by listing things to remember when executing the projects. The document did not go into detail of the project process but was considered great support for the framework development.

3.3.3 Observation of lessons learned

The research also used observation as a data collection method. Observation is a data collection method used mainly in qualitative research where the researcher observes events, people, or behavior (Ekka 2021). Observation provides the possibility to experience firsthand the observed subject rather than relying on another person's perception of it. However, the data collected by observation is susceptible to researcher's bias and it cannot directly explain the reason behind the observed subject. The researcher had the opportunity to attend lessons learned feedback sessions of two of the case company's larger fuel conversion projects. As Cohen (2014) pointed out, lessons learned from previous projects can be used in upcoming projects to avoid similar mistakes and achieve greater success. Therefore, the lessons learned from the observed session was used to increase the performance of the PMF and link it to practice.

3.3.4 Workshop

The last method of data collection was a workshop held once the first version of the PMF had been developed. The purpose of the workshop was to present the PMF to the stakeholders and to provide an opportunity for feedback to further develop the PMF. The literature emphasizes the importance of the involvement of the stakeholders of the framework in the development to reduce the risk of failure (Naybour 2014; Duggan & O'Neill 2013). Therefore, the workshop was considered critical to increase the involvement of the department members in the development.

Furthermore, Ørngreen & Levinsen (2017) state that workshops create data that differs from the data collected from interviews and observations. Workshops can contribute to gaining deeper insight or new perspectives to a phenomenon which was not considered prior to the workshop. There are different types of workshops with different goals, a problem or product can be presented, analyzed, discussed, developed or all the mentioned. Ultimately, the collaboration of the participants creates a more comprehensive view of the phenomenon.

The intention of the workshop was to present the first version of the PMF to the participants and through discussion validate the correctness, accuracy, and usability. Furthermore, overall feedback and ideas for improvements were collected. After the workshop the PMF was revised based on the response. The participants of the workshop were three out of the five interviewed team members, the manager of project engineering and the department's general manager. The latter two where not part of the interviews but the manager of project engineering had worked as a project manager in fuel conversion projects prior to his new assignment. The participation of these two people ensured that the PMF was validated from another viewpoint than the ones of the interviewed department members.

3.4 Data Analysis

The data analysis method chosen for the research was constant comparison. The method uses coded categories which are found in the data (Williams 2019). As the name implies the data in the formed categories is constantly compared between each other and connections are established (Williams 2019; Lewis-Beck et al. 2004). The categorization and comparison make the method good for both arranging and processing of data (Williams 2019).

The data analysis process began with the researcher's immersion in the data. Savin-Badin & Major (2013, p. 420) argues that processing the data multiple times before beginning to analyze helps in understanding the holistic picture of the data before dividing it into smaller pieces. The following step was the coding process where relevant recurring processes and activities mentioned by the interviewees were picked out (Savin-Badin & Major 2013, p. 421—422). Coding is useful to find specific information that was frequently mentioned by the interviewees. The information is given a category or name to support the comparison, searching, and assigning of data. The main processes of the fuel conversion projects were first identified and then smaller activities of these were sought for the PMF development. Similarly, main categories were picked out from the challenges, organizational structures, and success descriptions. The categories found in each transcript, observation and document were then compared between each other to find the common factors.

3.5 Research Quality

Interpretation of research quality is challenging because appropriate research quality depends on several factors (Langfeldt et al. 2020). In addition, there is little standards or defined descriptions for evaluating research quality available (Mårtensson et al. 2016). However, there are several strategies that can be utilized to ensure greater quality of the research of which the research implemented several. First, the research used triangulation in the theory, data collection, and choice of interview respondents. By not using only one theme in the theory, one type of data, nor one type of department member in the interviews the research increased its trustworthiness by expanding and diversifying the information collected and used (Bowen 2009).

Secondly, the feedback workshop supported a strategy called member checking. When member checking is utilized, the data collection is evaluated by the participants of the study to ensure that the researcher has understood them as intended (Birt et al. 2016). Member checking can increase the credibility and trustworthiness of the research since the content created based on the response in interviews can be examined using the method. Member checking also provides an opportunity for the participants to comment on the value of the research findings (Tracy 2010). The workshop acted as a tool for conducting member checking. The workshop session gave the respondents the possibility to check that the researcher had captured their experiences of fuel conversion projects correctly and transformed them adequately into a PMF. Furthermore, the participants of the workshop could voice their opinion of the usability and value of the PMF for the department.

Thirdly, the researcher had some experience about the topic since he had worked in the department for a short period of time prior to beginning the research. Experience in the field or topic can support the research credibility by ensuring that the researcher understands the field and its practices, terminology and more (Tracy 2010; Savin-Badin & Major 2013, p.477). Albeit experience in the field can cause bias it was still seen as beneficial since the interview questions could be designed to get more comprehensive answers and understanding. Finally, the chosen data analysis method, constant comparison, is regarded to support the credibility of the research (Lewis-Beck et al. 2004). The abovementioned strategies were chosen to increase the research quality and trustworthiness by ensuring that the theory, data collection and results of the research were credible and transparent.

4 The fuel conversion project management framework

This is the results chapter which presents the fuel conversion PMF that was developed based on the data collection. The chapter begins with a short introduction to the case company. Thereafter, each part of the framework is presented. This chapter describes the fuel conversion project at the same time the PMF is presented thus, it naturally answers the first research question, RQ1: what does the fuel conversion project process look like?

4.1 Case company introduction

The case company is a global company operating in the marine and energy production sector. One of the company's main markets is providing different solutions for energy production in form of engine power plants. Part of their portfolio among other is complete new build engine power plants and upgrades to already existing power plants. The PMF was developed for the project management department for the latter. The case department has 31 employees at the moments that have roles of managers, project managers, project engineers, project planners, and coordinators. The case department is responsible of managing projects that are done to existing power plants which are upgraded, modified, or re-built with the objective of maintaining current performance, increasing performance, lower operating costs, staying competitive or gaining environmental benefits. This is realized by upgrading components of the engines, upgrading the electrical or automation system, replacing or adding complete engines, rehabilitation of equipment, or converting the engines to run on other fuel sources. The project type is based on what is upgraded or modified.

Therefore, one of the project types is fuel conversion projects where a power plant is modified to run on a different fuel source than the power plant was originally designed for. Fuel conversion of a power plant is a way to reduce the operational costs due to lower fuel and lube oil consumption, gain environmental benefits by reducing emissions, gain flexibility in the power production by utilizing multiple fuels, and increase the lifetime of the powerplant. However, this requires significant modifications to the engines of the power plant, their automation systems, supporting auxiliary systems, and sometimes civil structure. This makes the scope of these projects large and often complex which require competent and experienced project team members and successful PM. The department has performed fuel conversion projects in the past and has ongoing fuel conversion projects. The forecast indicates that there will be an increase of these projects in the future. Thus, it was seen as appropriate to create a PMF to support the execution of the upcoming projects.

4.1.1 Project management at the case department

To have a better understanding on how the developed PMF is placed in accordance with the existing PM model in use at the case company the PM model is presented shortly. The case department follows the governing companywide project model used in the case company's projects. This model is based on the Project Management Institute's Project Management Body of Knowledge, PMBOK® Guide. The project model is a stage-gate model where a project is split into different subsequent stages and is passed to the next stage once the gate criteria for the next stage is met. A project at the case department is split into the following stages, initiate, plan, execute, monitor and control, and close. These stages are located on the project lifecycle which consist of project sales, project delivery, warranty and in some cases life cycle support. The gates of a project are G0: go/no-go, G1: decision to offer, G1A: decision to submit detail offer, G1B: decision to sign, G2: start of execution, G3: delivery is handed over to the customer, and G4: warranty period of the installation is over. The developed PMF specifies the project delivery by dividing the delivery into smaller phases presented in the next sub-chapter. Therefore, the PMF excludes the sales and warranty phases of the project. Figure 7 illustrates the case company PM model.

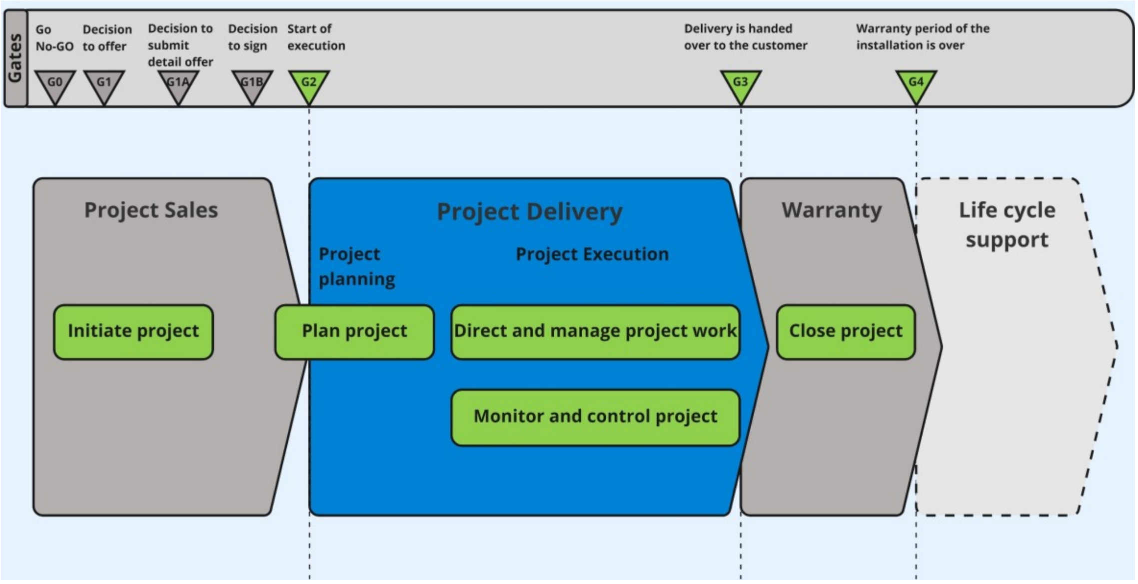

Figure 6. Illustration of the project model in use at the case company.

4.2 Structure of the framework

The standalone fuel conversion PMF document consists of three main parts, a summary table, a visualization of fuel conversion projects' main project activities, descriptions of each project phase, project challenges, and success metrics. The purpose of the summary table is to provide a fast way to get a high-level overview of the objectives and main outputs of each phase of the project. Thus, it creates the foundational structure of the PMF and basic understanding of what is done in fuel conversion projects. The visualization of main project activities dives deeper into what the main activities are and illustrates how they are associated to the project timeline and each other. The descriptions of each project phase aim to describe the main project activities in more detail and other things to remember when executing the respective phase. Furthermore, the descriptions of fuel conversion project challenges aim to inform common challenges that should be kept in mind when planning and executing a project. Finally, the project success metrics provide goals to strive for in projects. The fuel conversion PMF's summarizing visualization can be viewed in figure 8 and the visualization of project main activities in figure 9.

The fuel conversion project framework					
	Initiation	Engineering	Procurement	Logistics	Site Works Preparations
Objectives	• Understand the contract in terms of project scope, technical specification, and requirements • Plan the project execution • Begin long lead time and critical project activities	• Engine design, auxiliary systems, and plant design are engineered based on scope, current layout, and condition of the power plant • The designs achieve contractual obligations of engine and plant performance • Engineering for systems with long lead times are finished early • New design fit with old design	• All required material is procured and within schedule • Long lead time material is procured early • Material costs comply with the budget	• Transport all material from suppliers to the site within schedule • Fulfill the delivery terms • Transportation costs comply with the budget	• Successfully convert the powerplant to run on new fuel source within schedule • Accomplish the contractual obligations of engine and power plant performance • Preparations are stated early • Achieve customer satisfaction
Main Outputs	• Established project team • Defined project scope, budget, and schedule • Project activities with long execution time are started • Information of power plant • Customer relationship development is started • Site manpower availability are pre-screened • Stakeholders are mapped • Documentation requirements	• Early basic design for auxiliary systems • Main flow diagrams and device lists • Detailed engine design, auxiliary systems design, and plant design • Pre-assemblies for systems and components where possible • Engineering documentation	• Procurement plan • Correct material procured according to scope, engineering, standards, and regulations • Correctly packed and marked packages • All needed documentation and certifications are delivered with the material • Systems are pre-assembled where possible	• Shipment plan • Container stuffing plan • Correct packing for materials • Booked transportation • Export documentation for the shipments • Customs clearance prepared • Location country transportation • Sub-contractors for transportation booked	• Site execution plan • Site works schedule • Site organization • Site manpower acquisition • Facilities and social amenities for site organization • Permits, insurance, training, and tools for site organization • HSE procedures • Site quality plan • Site logistics plan • Site procurement plan • Commissioning plan • Converted engines • Engine handover

Figure 7. The fuel conversion project framework summary table.

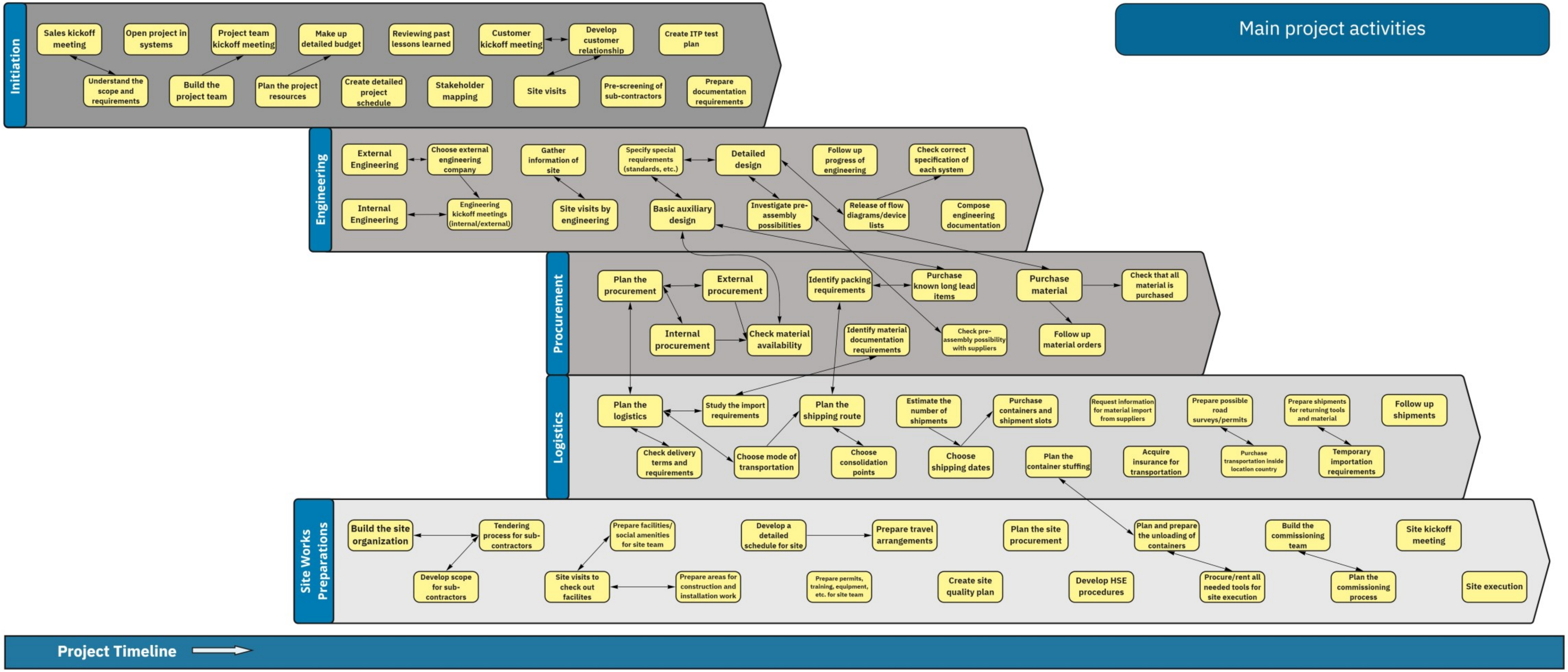

Figure 8. Visualization of the main project activities fuel conversion projects.

The governing table in figure 8 is a summarizing visualization of the framework. The visualization is inspired by the structure presented in Trentim (2020) but modified to fit the need of the case company's fuel conversion projects. The columns of the table represent the different phases of a fuel conversion project. The first row of the governing table describes the objectives of each phase. The objectives were created from the critical factors of each phase and the descriptions of success that the respondents gave. The second row of the summary table describes the main outputs of the project phases. These are the outcomes that the main project activities produce. These are described extensively in each phase's sub-chapter and are visualized in figure 9. The project timeline can be viewed at the bottom of the visualization. Each phase of fuel conversion projects is represented by an arrow shaped box. The main project activities performed in each phase is represented by rectangular boxes in each phase. In addition, arrows illustrate that a project activity is dependent by the connected project activity.

4.2.1 The five phases of a fuel conversion project

When the respondents freely described the fuel conversion project process, five main phases of the project execution stood out quite clearly since every respondent referred to these in some way, albeit with varying names. The researcher had also identified these phases prior to the interviews through observation. This allowed the interview guide to focus on gaining insight to these main phases of the project's execution. The five phases that creates the main body of the PMF are *initiation, engineering, procurement, logistics,* and *site works preparation.*

The respondents referred to these phases by names already in the interviews, but with some deviation for example, respondent 2 used the term *delivery* when describing the logistical activities, and respondent 4 used *transportation* instead. The fuel conversion introduction document also used the term *transportation* for the logistical activities. Furthermore, when the respondents described activities done in the beginning of the project, they referred to no umbrella term but rather just listed things done before advancing to the engineering. Therefore, unified names for each phase were created. Suitable names for the phases were chosen by the researcher based on the terms used by most of the respondents and terms used in case company documents. The names were validated as appropriate in the workshop.

The purpose of the five phases is to represent the main processes of fuel conversion projects and create categories for where the project's main activities are done. These phases were already used in the PM and communication of the project teams and thus, created the phases of the projects. They are also referred to as project phases to reduce confusion with the stages of the case company's PM model. It became apparent in the interviews that the phases are not chronologically exclusive phases and thus, one is not followed by the next once the previous is completed. Rather, the phases overlap each other and many project activities are performed simultaneously and are also dependent on activities performed in other phases. This is illustrated more clearly in the visualization of the main project activities in figure 9. The visualization illustrate that the project phases begin at different time of the project timeline but are still performed alongside each other. The main project activities are also linked to activities in the other phases as the arrows indicate. Figure 10 illustrates how the phases of the PMF are in relation to the case company project model.

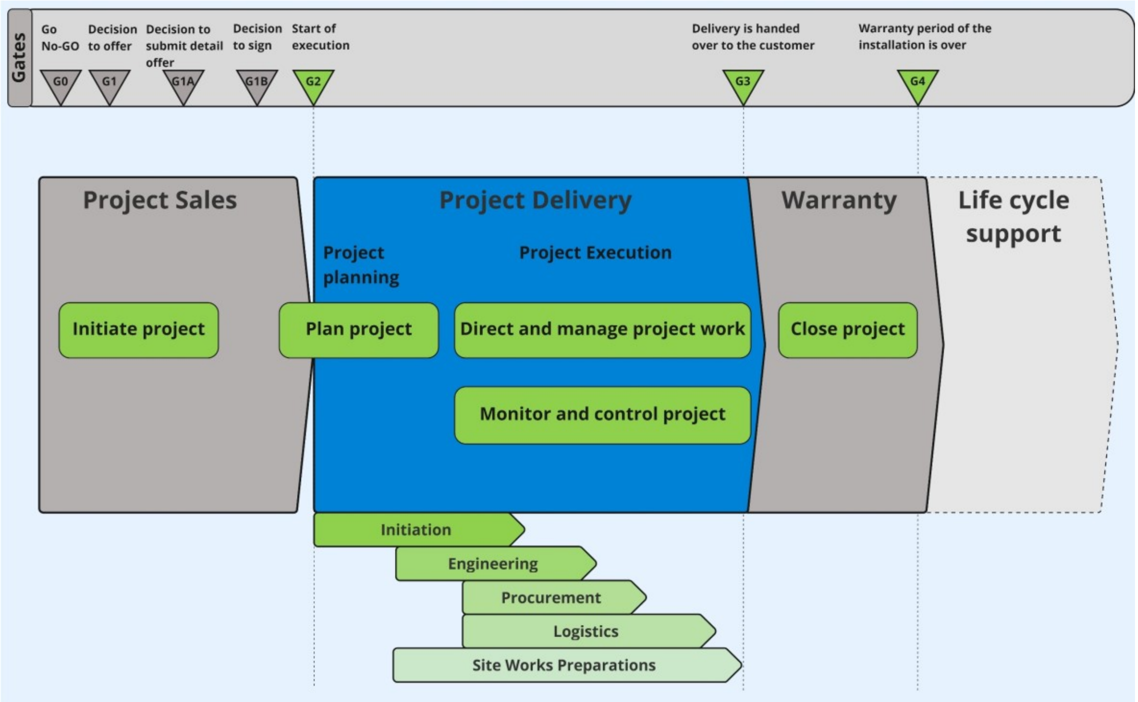

Figure 9. Illustration how the fuel conversion PMF is located in relation to the case company's PM model

4.3 Initiation phase

The initiation phase includes the project activities that are performed in the beginning of the project execution and begin before the engineering phase. The initiation stage begins after the contract of the project is signed and is officially handed over from sales to the project team and thus, is put into project delivery according to the case company's PM model.

4.3.1 Initiation phase objectives

All respondents stated the importance of understanding the contract comprehensively in terms of project scope, technical specification, and requirements. These form the foundation of producing the deliverables of the project and therefore must be understood completely. Also, requirements verbally discussed between sales department and customer must be known by all stakeholders as these must be addressed as well. Furthermore, modifications to the scope must be recognized and communicated to all stakeholders. Therefore, the understanding of the contract and project scope forms the first objective of the initiation phase.

Another critical factor pointed out especially by the project managers was the importance of planning the project schedule and budget. Which is inherently a major part of the initiation phase. The cost calculation and schedule that is developed in the sales phase must be further specified to project, customer, and project team requirements. Based on this, planning the project execution was decided as the second objective of the initiation phase.

The third objective of the initiation phase is that project activities with long lead time are started. The schedule of a fuel conversion project is usually limited and therefore, long lead time activities for example, engineering, documentation, and procurement of some material can affect the schedule extensively if not begun early and managed effectively. Thus, also the planning of these activities must begin early. There is currently a push at the department that some of these are prepared to some extent already during the project sales. But the PMF considered the activities as they are performed now.

4.3.2 Main project activities of the initiation phase

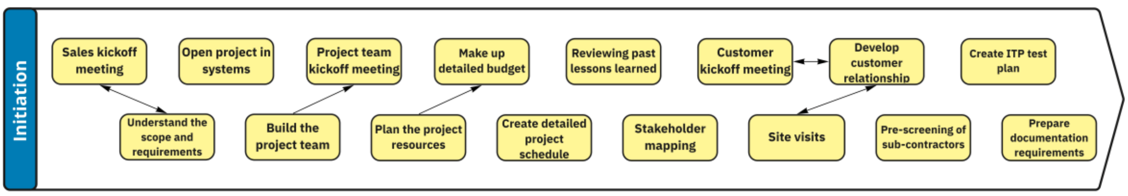

Figure 10. The main project activities of the initiation phase, extracted from figure 9.

The first activity for the project team once the contract is signed is to have the sales kickoff meeting with the sales department. In the sales kick-off meeting the contract is analyzed and the project scope and requirements are understood. In the early beginning of the initiation the project is opened in the different systems the company uses for example, the enterprise resource system, documentation database, etc.

A natural activity of any project is to build the project team which is responsible of the project execution. In fuel conversion projects the core project team consists of a project manager and project engineers for mechanical and electrical work, usually one of each. In addition, there are other stakeholders such as project planners, supply chain coordinators, purchasers, and a project controller. Furthermore, the project team is supported by other stakeholders such as engineering team, site team coordinators, technical experts and so on. Once the project team has been constructed a project team kick-off meeting is held. In this meeting the contract is analyzed further so the contract and the scope of supply and what will be delivered is understood by every team member. The roles and responsibilities of each team member are defined in this meeting and tasks are assigned a team member, so no tasks are left undone. It is important that everyone knows what their role, targets and goals are. Furthermore, key issues or challenges which may arise during the project can be analyzed and measures against them can be planned.

Once there is a clear understanding of the contract and project scope, planning of resources begins if it has not been started prior to the signing of the contract. However, even if so, the budget is updated and specified in the initiation phase to ensure it aligns with the latest version of the scope of supply. The project schedule is also developed to a more detailed version at this stage. The financial, manpower, support teams and other resources are validated to make sure they are sufficient to reach the goals of the project.

The case company puts emphasis on lessons learned from all their projects to utilize them in upcoming projects. Therefore, reviewing lessons learned documents from previous fuel conversions is done to avoid similar challenges and to implement things that worked. Similarly, discussing with the department members about previous fuel conversion projects is commonly done as form of verbal lesson learned discussion. This activity was not included in the first PMF version but in the workshop respondent 3 pointed out that this should be included in the initiation phase because of the value it can bring to a new project.

Another project activity which was included in the PMF following the workshop was stakeholder mapping. This was pointed out by the manager of engineering. Stakeholder mapping in fuel conversion projects is done to know who can be contacted if issues arise thus, building a local network of people. Here, the stakeholders are often from support structures of the department.

In the beginning of the project, developing the relationship with the customer is also begun. A customer kick-off meeting is held where the project team and the customer team is introduced to each other. The scope and technical specification are gone through again but here from the customer perspective, to ensure that they represent their expectations. Possible special requirements of the customer are also discussed. Discussing what the key matters of the customer are for example, emphasis on safety is an important part of the meeting. The customer kick-off meeting is also for deciding practicalities such as contact persons, who can speak English and who might need translation, meeting interval, what reporting they expect and so on. Furthermore, ensuring that the customer understands their responsibilities is crucial. Site visits are also done to foster customer relationship and simultaneously gather information of the site layout and condition.

One project activity with especially long lead time is the acquirement of sub-contractors for the conversion and installation work at site. Therefore, pre-screening of possible sub-contractors is done already in the initiation phase to map out potential sub-contractors and to speed up the acquirement when the needed input from engineering is received. This project activity is quite challenging since there must be designs from engineering phase to create the scope for the sub-contractors to base their quotations on. However, the pre-screening can still speed up the process when done earlier in the project.

Another project activity that must be started in the initiation phase is the project inspection and test plan (ITP). This plan is the input for quality control of the projects and is needed for the site quality plan development later. For other project documentation,

documentation stakeholders are involved already at the initiation phase or at the latest at the engineering kickoff meetings. The stakeholders responsible of documentation need the required input to know what and how the documentation will be developed. The documentation requirements can come either from the contract itself but will need input from the project team as well.

4.4 Engineering phase

The engineering phase includes the project activities that relate to the engineering of modifications to the power plant that is done for the fuel conversion to be possible. The engineering is a prerequisite for many of the procurement and site works preparation activities. Therefore, the earlier the engineering is completed the faster these activities can be finalized. However, the engineering comes with its own challenges and proper quality of engineering is crucial to avoid rework at a later stage of the project which can result in major cost deviations and schedule delays. The engineering is usually split into internal and external engineering. The engine related design changes are performed internally by the case company's engineering department and the design of auxiliary systems, automation, electrical systems, and civil structures are done by one or several external engineering companies.

4.4.1 Engineering phase objectives

The first objective of the engineering phase is that the engine design, auxiliary systems, and plant design are engineered correctly according to the scope, current layout, and condition of the power plant. It is crucial that the engineering teams base their designs on the scope of supply and the current state of the power plant to avoid re-engineering. Re-engineering is costly and uses critical time that can be used elsewhere. If the power-plant is older or in bad shape it usually increases the amount of work and the importance of collecting information before starting the engineering. Multiple respondents mentioned this as one of the critical factors of engineering.

The second objective of the engineering phase is that the engineered designs can achieve the performance obligations set in the contract for the engines and the power plant. To fulfill customer expectations, the product must fulfill the requirements set for it. Here, the importance of engineering quality is highlighted again. The persons responsible of the engineering must understand the scope completely for them to be able to engineer designs which fulfill the performance and customer requirements.

The next objective of the engineering phase is to design systems with components that have long lead time or complex systems with long manufacturing time first for them to be completed as early as possible. This is important so the delivery of materials, components and systems are within schedule. In practice, it is not always known which materials have long lead time but the engineers should have some knowledge about lead times of components so they can prioritize the design which contain long lead time components.

The final objective of the engineering phase is that the new designs of engine, auxiliary, and power plant fit with the existing application. In fuel conversion projects the converted engines are often older engines which are not offered by the company anymore as so called “portfolio engines”. Therefore, the new design must comply with the old and its systems and components. The importance is highlighted for expensive components such as the turbocharger. Furthermore, many of the parts from the old engine are reused in the converted engine so standalone components, not part of a specific system, must be checked that they fit as well.

4.4.2 Main project activities of the engineering phase.

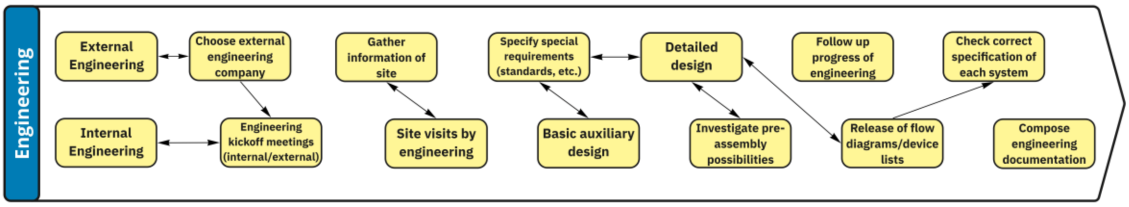

Figure 11. Main project activities of the engineering phase, extracted from figure 9.

The first activity of the engineering phase is choosing external engineering companies responsible of designing the modifications set in the scope for auxiliary, electrical, automation, and civil systems. The case company usually selects engineering companies they have previously worked with. Once the engineering company or companies are chosen a kick-off meeting is held with each company. Similarly, a kick-off meeting is held with the internal engineering team responsible of on-engine design. In the meetings the scope for the respective engineering team is gone through and requirements for the engineering are set, out of which the time schedule is one of the most important. In the kick-off meetings practicalities are also planned for example, follow-up meeting frequency and communication. The practicalities help in following up the progress of engineering which is done throughout the engineering process.

As stated by the objectives for the engineering phase, investigation of the current layout and condition of the power plant is very important. Here, the project team give input they have gathered but, in some cases, site visits by the engineering teams are necessary as well. The more and better information the engineering teams have the higher quality the engineering becomes. Furthermore, the engineering teams must be informed of any special requirements that apply to the location country of the project or the power plant itself. Examples of these are, country specific standards of components such as US or Australian standards or requirements on components located in safety critical environments e.g., prone to explosions or fire.

A project activity that greatly improves the speed of procurement is a basic design for the auxiliary systems. This is done early, possibly already in the sales phase. The design should include a base for the site layout, the location of the auxiliary units and main flow diagrams. This enable the design of the auxiliary systems to be finalized sooner and thus, the procurement of material with long lead time to begin earlier. The basic design functions as the foundation for the detailed design done later in the engineering phase. Based on the detailed design created, pre-assembly or modularization possibilities can be investigated by the engineering teams. If systems are pre-assembled before shipped to site, it improves the logistics and installation time. Pre-assemblies can often be done for some of the engine components, automation systems, and auxiliary units. Once the designs of engines and auxiliary systems are completed, the drawings, flow-diagrams and device lists are released subsequently for the project team to procure the material.

As laid out by the objectives of the engineering phase, correct specification and fitment of new and old components must be ensured. Therefore, once the designs are released, they must be validated as correct. With correct design and specification from the get-go, unnecessary rework is mitigated. Usually, the later the need for rework is recognized the more consequences it has. Finally, once all engineering work is done the documentation for example, drawings, red pens, etc. of the project is composed, gathered, and updated for the project’s power plant.

4.5 Procurement phase

The procurement phase begins at the same time as the logistics phase since both are planned together. The procurement and logistics phases are very dependent of each other and therefore, are planned in a procurement and logistics plan. The procurement phase includes all project activities related to procurement of materials for the project. Procurement is the main way how the material flow can be managed and in combination with the logistical activities it determines how the material arrives at site. The material procurement activities themselves begin once the necessary input is received from the engineering teams once the first designs are completed. The procurement is split into internal and external procurement. The case company has a large warehouse of material and components which are utilized through internal procurement, usually engine and engine related components. Moreover, there is still material that is procured from sub-suppliers, generally auxiliary, automation, electrical, and civil components.

4.5.1 Procurement phase objectives

The main objective for the procurement phase is that all required material is procured and within the planned schedule. Fuel conversion projects require procurement of a lot of material and components which emphasizes the carefulness of procuring every needed item. If missing material is discovered at site, it can have costly consequences since the installation work may be stalled, local procurement can be challenging, and material delivery can be lengthy and expensive. Naturally, the material must be procured in time for it to make it to the main shipments to keep delivery costs down.

The second objective is also connected to the schedule which is that the procurement of material with long lead time and thus delivery time is done as early as possible. This was emphasized as a critical factor by most of the respondents. Long lead time components can be material that have long manufacturing time or items needed in large quantities and thus, take longer to be completed. Procurement of long lead items must be done directly when the input from engineering is received. This enables the long lead items to be transported with the main shipments. The third objective of the procurement phase is that the costs generated by the material procurement are within the budgeted value. Material costs are a big part of the overall cost of the project and thereof cost management is critical.

4.5.2 Main project activities of the procurement phase

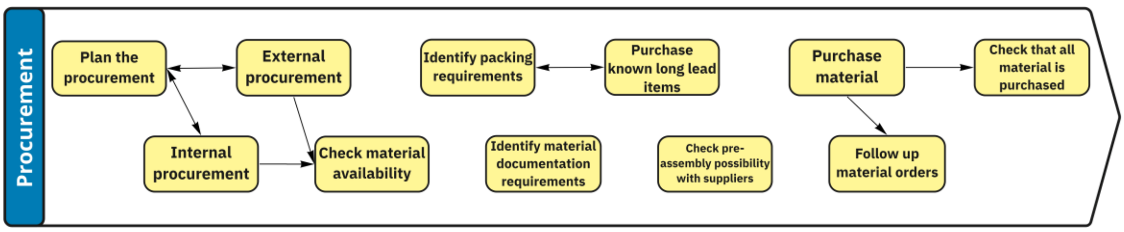

Figure 12. Main project activities of the procurement phase, extracted from figure 9.

Like stated in the beginning of this sub-chapter, the procurement phase begins with planning the procurement in combination with planning the logistics of the project. The supply chain coordinators, warehouse stakeholders, and engineering teams are involved in the planning. The planning begins with deciding what material is purchased internally and what externally. It is important to consider the transportation schedule laid out in the logistical planning in the procurement planning to set days when material must be delivered latest to the consolidation points. This is crucial information for the suppliers.

A major activity part of the procurement planning is to plan how the material will be packed for transportation. This decision is highly dependent on the mode of transportation and transportation route which in turn, are project activities in the logistics phase. The packing is also affected by how and for how long the material will be stored at site. Rust occurring due to long storage times and climate in the location country has been a problem in earlier fuel conversion projects. Therefore, deciding the correct packing type and possible additional protection is important. Furthermore, part of planning the material packing is specifying the marking of packages. Package marking affects how easily material is identified at site and unified marking is preferred. These are the first project activities of the procurement phase. Immediately when basic designs from engineering teams are handed to the project team, material availability are checked both internally and externally. Here, the identification of long lead items occurs.

Before material is purchased, needed material documentation must be identified. First, if the material or the component has material standards, safety requirements, testing, etc., certificates for these must be requested from the sub-supplier. Secondly, depending on the import requirements of the location country, information about the material may be mandatory for example, harmonized system (HS) code, manufacturer, country of origin, etc. Experiences from past projects show that these must be requested from the sub-supplier upon ordering since it is challenging to receive these if requested later. Another thing checked before material or components are procured is the possibility of pre-assembly of systems. The pre-assembly reduces the amounts of packages thus, making the logistics easier.

When the procurement and logistics plan is completed, and the basic designs and or detailed design are provided by the engineering teams the procurement of material is begun. The procurement starts with long lead items and hopefully the designs for these are completed first. Based on the background check of material availability, the long lead items purchase can be prioritized. The material and components are then procured incrementally with the release of more designs. During this process the material orders should be followed up regularly to ensure they are sent and received by the required days. Ideally, all material is procured before the main shipments, but sometimes additional material is required or realized later and procured either from Finland or the location country at a later stage. However, before the last shipment the material orders are checked to ensure that all required material is procured.

During the workshop two valuable things to remember where mentioned by the manager of engineering. First, it is important that the procurement is retrofit applicable. This means the material sub-suppliers must be informed that the components will be for retrofit projects. The company also order parts for newbuild powerplants and possible needed extra material for retrofit projects are not included. Secondly, the packing must be similarly retrofit applicable because the unloading tools at site are not always like that of manufacturing lines. Furthermore, linking to the need of increased protection, the packing cannot be only for indoor storage.

4.6 Logistics phase

The logistics phase is begun at the same time as the procurement phase with the combined planning. However, the logistical activities are their own phase because they differ from the procurement and last for longer relative to the project timeline. The logistics phase includes project activities regarding the planning of transportation of material to site, the material import preparations, and performing transportation.

4.6.1 Logistics phase objectives

The first objective of the logistics phase is to successfully transport all material from the suppliers all the way to site within the planned schedule. Naturally, without material the fuel conversion cannot take place. Therefore, the delivery of material must be done for the site works to begin. It is important to have the material at site at the intended time since it is expensive to have the site team and customer waiting. Therefore, the logistical activities require rigorous planning.

Depending on how the project is sold the logistical responsibilities can vary greatly depending on what the delivery terms are. In some projects the company's responsibility is for example, to get the material to the transportation vehicle and in some to transport it the complete way to site. Whatever the delivery terms are, these are contractual obligations that must be met. Additionally, special agreed requirements must be considered as well. Therefore, this forms the second objective of the logistics phase. The third objective is that the logistical costs are kept within the budgeted value. Because of the large amount of material that is needed for fuel conversion projects the logistical costs can become quite high and thus, can affect the project profitability if deviation occurs.

4.6.2 Main project activities of the logistics phase

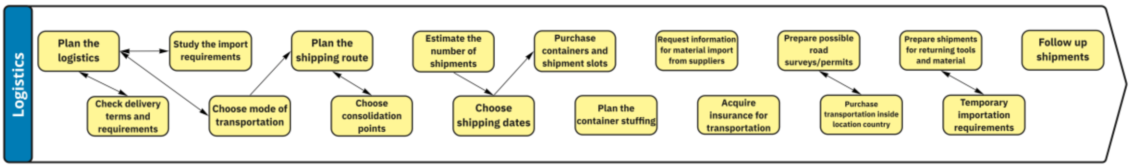

Figure 13. Main project activities of the logistics phase, extracted from figure 9.

As mentioned earlier the first task of the logistics phase is to plan the project logistics in combination with planning of the procurement. There are quite many things to consider in the logistical planning and therefore stakeholders, mainly the project team, logistics coordinators and the site manager are included in the planning. The logistical planning includes the essentials for moving the material to the site and how this is done most effectively both from time and cost perspective. To be able to plan and manage the logistics it must be clear what the company's responsibility is and what the customer's is. This is stated in the contract however, clarifications from the customer or sales department are sometimes needed.

Choosing the mode of transportation is the first decision of the logistical planning. Usually, the material is transported by sea freight but in some cases, airfreight is also used. When the transportation mode is clear the shipping route is planned all the way from the suppliers to the site. As part of the shipment route planning, the consolidation points are decided. Normally, the material is collected at one or several consolidation points to then be transported in larger shipments to site. The shipment route planning is affected by the delivery terms as only the route the company is responsible of is planned. Furthermore, the number of main shipments is decided. The number of shipments is affected by the amount of material, when the material is needed at site, and the delivery times of the material. The goal is to deliver all material in the main shipments but for material which delivery time exceeds the shipment date, rest deliveries are prepared too.

A project activity that is performed early in the logistics phase is the investigation of the location county's import requirements. Countries has customs processes that can vary significantly from each other hence, the requirements must be identified early to enable preparation and acquirement of needed documentation. This is an input for the procurement of material since the information must be requested upon making orders. The time of clearance through the customs can vary a lot between countries which make it important to consider in the logistics schedule. The customs clearance process itself can be part of the customer's responsibility but even if so, the project team is obligated to support with needed information and documentation.

Another project activity which is done as preparation for the transportation of material is planning the container stuffing. In practice this is how the material is packed into the containers. The order which the materials are packed into a container have impact on the efficiency of the internal logistics at site and reduces the possibility of damaged material. When the material is packed according to when it is needed in the conversion process and documented how the material is packed, it reduces the searching and movement of packages at site. Maximum size of boxes is also decided so that they will fit inside the containers and minimize excess empty space of the boxes. For very large components special containers may be needed. The larger and heavier components there are the better the planning must be. It is also crucial to consider the unloading capabilities at site when planning the container stuffing.

When the planning and preparations for the transportation of material is done, containers and shipment slots can be purchased. Depending on the current availability of containers and shipment slots they sometimes are soft booked in advance to ensure the shipment of material can be done at desired dates. Before the material is shipped the deliveries must be insured. In some cases, different insurance may be needed for the transportation to the location country and the transportation inside the country. If the transportation from the port to the power plant is in the company's scope, road permits may be needed and must be acquired if so. Furthermore, the roads are to be audited to ensure capability of heavy transportation. Naturally, the actual transportation must be purchased as well. Usually, the transportation is performed by a local transportation company.

Another important activity of the logistics phase is to plan and prepare deliveries for tools or material which will return from the power plant. For these items the import requirements may differ from the items which will not return, and thus temporary import documentation may be needed depending on the location country. Finally, when transportations are in action, they are followed up, so all material is in the intended shipments and that the deliveries are updated in the company's tracking system.

4.7 Site works preparations phase

The site works is where the actual fuel conversion of a customer's power plant is done and includes all work done at the power plant site. Sometimes this is also referred to as site execution. This work requires a lot of preparations that support the work done at site. These preparations are begun significantly earlier than the work at site begins since these activities have long lead time and must be completed at the latest the first day of site execution. The case department has a separate handbook for site related tasks and the mapping of the tasks done at site execution would not have been possible in the realms of a master's thesis. Therefore, this phase is called site works preparations and includes all work that is done prior to the actual conversion work begins.

4.7.1 Site works objectives

The first objective of site works is to successfully convert the powerplant to run on the chosen fuel source within the schedule. Although, the PMF focuses on the preparations of the site execution this is still the main goal of the phase. The site works include many tasks which must be done in a very tight time schedule which must be kept since the conversion work require the downtime of the customer's engines. The second objective is that the power plant reaches the contractual obligations on engine and plant performance after commissioning. If these are not met the project cannot be considered successful and customer satisfaction is significantly lessened.

The third objective of site works is that preparations are started early. Because of the tight time schedule, rigorous preparations are needed and must be in place so the site team can focus completely on the conversion work once they arrive to site. Some of the preparations are time consuming tasks with long lead time hence, the earlier they are started the better. Finally, the fourth objective is that customer satisfaction is achieved. During the site works, the customer can continuously view the work of the site team and can base an opinion of how well the modifications to their power plant is executed and how well the project is performed. Ultimately, all parts of the project must help in achieving the best customer satisfaction possible.

4.7.2 Main project activities of the site works preparations phase

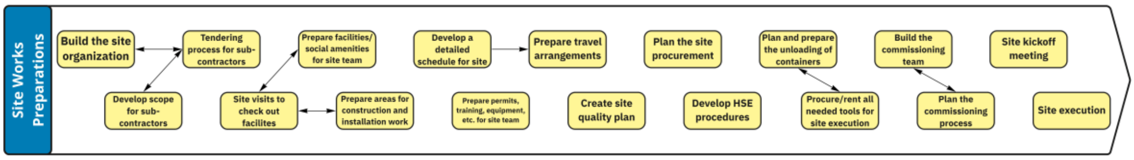

Figure 14. Main project activities of the site works phase, extracted from figure 9.

The project activities of the site works phase, build the site team, develop the scope forsubcontractors, tendering process for sub-contractors, and building the commissioning team, are extensive project activities and will be presented separately in the next subchapter. Some of these project activities are still begun earlier in the project.

Similarly to the engineering phase, information about the power plant is needed for the site works preparations. The project team collects information about the site to enable the planning of which facilities can be used by the site organization during the site works. Examples of this is, where possible temporary facilities can be located, where containers can be stored and so on. This information is gathered during the site visits which are done in the initiation phase or during other site visits. Based on this information, preparations of facilities are started.

Facilities and social amenities are arranged for the site team to enable them to concentrate on their responsibilities. Usually, the sub-contractors handle their own preparations, thus the facilities are prepared for the case company's personnel. The site team needs at least, accommodation, offices for work at site, toilets, changing rooms, food and water service, and transportation. Some of these arrange themselves by the existing facilities at the power plant but the others are arranged with temporary solutions. Additionally, areas for construction and installation work are prepared for example, workshops, welding areas, and container laydown areas. If not available, electricity for the facilities and areas are arranged as well.

As mentioned earlier the activities in the site execution are time critical to respect the time reserved for the conversion work. Therefore, a detailed schedule for all site activities is developed in advance. The schedule is also important for minimizing the effect of other possible maintenance work that is performed at the power plant, since the work can be scheduled around these. Once the site organization has been developed and the schedule is finalized travel arrangements for the members of the site team are done. To ensure that work can begin on the planned date site personnel is flown out a couple of days beforehand for them to prepare their work. Furthermore, required work entrance permits, work permits, insurance, training, certificates, etc. are arranged for the needing site team members. This is done well in advance to be surely organized before the site team arrives to site.

To guarantee great quality of the work performed at site a site quality plan is prepared. The ITP plan developed in the initiation phase is a required input for the site quality plan. Another crucial preparation is the health, safety, and environment (HSE) procedures. Safety is of outmost importance at site and therefore, HSE procedures are developed to ensure maximum safety. The customers HSE procedures are also considered as these must also be fulfilled.

During site execution there might rise need for additional material that were not considered during the actual procurement. In that case there is need for procurement in the location country, called site procurement. This is also prepared in advance by creating a plan that assigns the responsibility of procurement to suitable persons in the site team, states available resources, and arranges training and access in procurement systems. Furthermore, the old and used parts must also be considered and disposal possibility or local scrapper need is investigated.

If the unloading of containers at site is the case company's responsibility, this is prepared. An external company with the capability of unloading all material is acquired. The unloading is planned, and responsibilities are assigned for each task. The planning also considers container location, which is highly dependent on the site layout. Containers are stored at the site or if there is limited space available, at a different location nearby the site. The location of each container is arranged to minimize excessive movement of material inside the power plant. Some sites can have warehouses that can be utilized. How the containers will be handled after they are emptied must be considered. To enable the unloading of the containers all required tools such as cranes and forklifts are arranged if not handled by the sub-contractor responsible of unloading. Similarly, tools needed for the installation work is also arranged in advance by procuring or renting them.

Moreover, commissioning of the converted engines is an activity that is prepared beforehand. Commissioning of an engine is usually done directly once it has been converted because it is often needed in the power production straight away. The commissioning planning includes how the commissioning of the engine will be done, what tests will be performed, and who will be involved in the process. Finally, before the mobilization of the site team and the site works start a site kick-off meeting is held with the people participating in the work. All mentioned preparations lay good foundation for successful fuel conversion and installation work at the power plant site.

4.7.3 Building the site organization

The site organization includes all people who are part of the work done at the power plant and in the fuel conversion of the power plant's engines. The site organization, also called site team, is built based on the need of manpower, thus dependent on the size of the scope. The site organization is created based on previous experiences of internal and external partners. The aim is to find the most suitable site team for performing the work. It is proven to be quite challenging and time consuming to find experienced and competent resources for the site team. Moreover, the local language can impose communication challenges. Therefore, the scanning of site manpower starts early in the project.

The first person the project team finds is a site manager (SM), who is the overall responsible of the work done at the site. The project team and SM create a draft site team with the minimum required resources. The team is updated along the project once more people are required. Usually, the site team consist of at least a SM, site engineer, automation engineers, and supervisors and sub-contractors for the mechanical, electrical, and civil disciplines. In addition, a logistics coordinator, HSE officer, and a site contract manager are often needed. The SM is the head of the site management. The SM must be experienced, have good communication, and collaboration skills. These skills help the SM to communicate effectively with the site team, customer, project manager, project team, and other stakeholders. In smaller projects and if the skillset of the SM is sufficient, the SM can act as a supervisor for one of the work disciplines. The site engineer works as the SM's right hand and can help in various tasks upon the need for example, reporting, coordinating, and arranging practicalities. The logistics coordinator is responsible of the movement of material inside the site. The contract manager can help in clarifying responsibilities and collaboration between customer and the site organization. The HSE officer is responsible of coordinating and supervising safety matters at the site. In smaller projects the SM or site engineer can be responsible of the HSE procedures.

Depending on the scope, supervisors are needed for mechanical, electrical, and civil disciplines. The supervisors manage their corresponding sub-contractors. The supervisors are either internal or external resources depending on the availability. If it is a large project the engine and auxiliary work can be assigned own supervisors for both mechanical and electrical work. The sub-contractors are usually acquired from the location country or if some special competence is needed, from specific systems' suppliers. The sub-contracting tendering process is a long process hence, started directly once the required input from engineering is received. The new designs determine how much work will be done to the engines, auxiliary systems, and the constructions of the power plant. Once these are designed, the scope of installation work is developed by each discipline's project engineers. Thereafter, the sub-contractors use the scope to present offers on the work. Sub-contractor teams are usually acquired for the following tasks,

- Engine dismantling, modification, and installation
- Mechanical work of auxiliary and plant constructions
- Electrical work for auxiliary and plant systems
- Welding work
- Site logistics
- Helping in various easy tasks for example, transportation, component cleaning etc.

The commissioning team is also a part of the site organization and is created in advance of the site execution to make certain adequate personnel is present in the commissioning process. Usually, the supervisors of mechanical, automation, and electrical on-engine work function as commissioning engineers. The engine superintendent act as commissioning manager. A HSE responsible is needed in the commissioning team. Furthermore, a quality documentation responsible is nominated, here the site engineer is a good candidate. The quality documentation is a quite strenuous task where the documentation must be coordinated, collected, compiled, and uploaded in the system thus, one person focusses solely on this. If there are special measurements to be conducted, measurement experts are included in the commissioning team as well.

4.8 Challenges of fuel conversion projects

The experienced challenges of fuel conversion projects are presented as a section in the PMF for the reader to gain understanding of what parts of fuel conversion projects to pay extra attention to when executing a project. On a high level there is challenges in keeping the project schedule and budget. As stated, the tight schedule and amount of work puts strain on the schedule and is now tested even further with current uncertainties of delivery times and material availability. This makes it important to start project activities early but, in some cases, it is challenging to do so. Similarly, the budget is quite susceptible to be affected during the project since the cost calculations done during the sales phase may not represent the real costs accurately enough. Ultimately, both the schedule and budget are influenced by many different challenges. The complexity of fuel conversion projects, and the use of both internal and external actors can lead to quite many changes during the project which in turn, can become challenging to resolve.

Quality of engineering was mentioned by several respondents as a challenge. Engineering is an input to many other project activities and if the input is bad, it risks rework which in turn affects schedule and budget again. The engineering process also has a challenge with a narrow selection of engineering companies to choose from. The respondents wish for increased flexibility. A different challenge mentioned by all respondents was challenges imposed by limited material availability. The current situation of longer delivery times is one reason and the second is the large amount of needed material which the company's internal warehouse struggle to supply.

Similarly, some of the tools needed for the modification of the engine has challenging availability. Limited availability is also seen in the manpower for the site team. It is currently challenging to find competent sub-contractors for the site works, especially on the automation side. Furthermore, in some projects, the sub-contracting is challenged by the cost of the offers presented in the tendering process being significantly higher than the budgeted value in the sales phase. Naturally, this affects the margin negatively.

The import of material to the location country can be very challenging depending on what import requirements the country has. Some countries require extensive information about the material that will be delivered to the country, which causes a lot of work for the project team. Furthermore, the customs clearance process can be lengthy which lengthen the delivery times. Also, regarding documentation, receiving documentation on time is a challenge. The delivery of engine manuals, spare part catalogues, and as-built drawings currently takes long time which result in the customer operating the engines before receiving documentation.

There were additional challenges brought up during the workshop. Fuel conversion projects involve a lot of people which makes the number of contacts to be in touch with high. This makes the management of the information flow to be rather challenging as well. The complexity and many activities of the projects create a challenge with keeping up with all ongoing things. Relating to these, it is challenging to get quick replies to questions asked from the supporting stakeholders of the project for example, from internal engineering or supply chain department. Another challenge that was mentioned in the workshop is achieving good quality of welding of pipes done at site. One reason for this is the limited cleanliness of the pipes.

4.9 Defining successful fuel conversion projects

Success metrics were included in the framework to give guidance to what to strive for in fuel conversion projects. The projects are naturally evaluated on key KPI's defined by the case company, but the project team members mentioned other factors they conclude project success on as well. The driving success metrics are completing the scope of the project on time and within budget. Additionally, achieving customer satisfaction is naturally very important. Without satisfied customers a project cannot be ruled successful.

In a successful project the work that has been performed is of great quality. This is similarly connected to customer satisfaction as doubtful quality cannot lead to customer satisfaction. Another success metric mentioned was that the warranty period is passed with low warranty costs. This is tightly connected to quality as great quality results in minimal work during the warranty period. A successful project also has few or no open issues after the site works. This means that all intended work is completed during the site works and no work must be performed at a later stage. Additional material or services sold to the customer during the project is an indication of success. Furthermore, safety is very important during the entire project. Therefore, one success metric is the fulfillment of safety requirements, and no injuries or incidents has occurred during the project.

The mentioned success metrics above are mainly related to PM, but the respondents also mentioned successes on a more personal level. First, the project team members should feel proud of their work and have a feeling of achievement after the project. This can come from various things happening during the project but if the targets and goals set by the project team themselves in the beginning of the project are met this will surely cause feeling of success. If the project team is pleased after the execution of a project the possibility that they will want to perform the next project is higher. Increased employee satisfaction also results in the team members staying in the department and the knowledge can be contained within the department. Secondly, if lessons are learnt, both positive and negative during the project, it is also considered a successful thing. The lessons learned builds knowledge for the team which can be shared for upcoming projects and to other department members.

5 Discussion

This chapter analyses and discusses the results of the data collection. First, the similarities of the case company's fuel conversion projects and literature on retrofit projects are discussed in sub-chapter 6.1. Thereafter, the development of the fuel conversion PMF is discussed in sub-chapter 6.2. Finally, in sub-chapter 6.3, knowledge transfer of fuel conversion projects is discussed and the second research question, how can a project management framework support knowledge transfer of fuel conversion projects? is answered.

5.1 Fuel conversions as retrofit projects

Comparing the case company's fuel conversion projects' process and their challenges many similarities to the literature covering retrofits can be identified. Already when the scope of fuel conversion projects is examined it aligns with the definition of retrofit term, because an existing power plant is modified and gains capabilities which were not present before the conversion (Marriam Webster Dictionary 2021). Furthermore, the reasons behind fuel conversion projects, to gain commercial, operative, or environmental benefits are like reasons behind retrofits Sanvido & Riggs (1993) and (Botello & Valdivia 2018) presented.

Many of the challenges of retrofit projects presented by the literature is seen in fuel conversion projects. The respondents mentioned the limited timeframe to perform projects multiple times during the interviews and described how it forces many project activities to be done fast and started earlier. Especially the time at site is critical to follow the planned schedule as an engine cannot be in use during the conversion process. The limited time was identified as a challenge by Botello & Valdivia (2018), Fox (2003) and Sanvido & Riggs (1993). The challenge and importance of collecting accurate information of the existing application was also pointed out by the same researchers. Collecting good quality information was shown to be very important for the success of fuel conversions as well. The lack of updated drawings mentioned by Sanvido & Riggs (1993) also affects the case company's projects. Furthermore, the challenge of combining new designs with existing design present in fuel conversion projects was also found in retrofit projects (Sanvido & Riggs 1993; Fox 2003).

Moreover, the importance of understanding the project scope and requirements was mentioned as a critical factor repeatedly by the respondents. This was emphasized to produce the correct deliverables and reduce the risk of rework. It draws similarity to the risk of unknown complexity caused by inadequately defined objectives and requirements of retrofit projects mentioned in Fox (2003) and the success factor of clearly defined project objectives mentioned in Botello & Valdivia (2018). The same research highlighted the risk of predetermined execution dates which can lead to limited availability of material and personnel. Similarly, limited material, tool and site manpower availability was identified as a major challenge in the fuel conversion projects. Finally, the sensitivity to changes occurring during fuel conversions was emphasized by the respondents was also realized as a characteristic of retrofit projects in Fox (2003). Some of the respondents mentioned that the later changes were made in the project, the more negative impact they usually have on the project execution, something also recognized in Fox (2003).

Success factors of retrofit projects mentioned in Sanvido & Riggs (1993) was recognized in the execution of fuel conversion projects as well. The respondents mentioned the practice of making background checks of sub-contractors if they are not known from before which was recognized in the study. A critical factor in line with the success factors in the research is procuring long lead time material as early as possible. Another success factor utilized is to place the site works during other service breaks done at the power plant to minimize downtime. However, this results in the need to respect other actors at site, which can make the schedule planning more challenging. Furthermore, site visits were encouraged in the study to collect information about the site, something which was done in the fuel conversion projects and was included as main project activities in the PMF.

As a result, the case company's fuel conversion projects can be determined as retrofit projects based on their characteristics and correlation with the literature. In turn, demanding the PM of fuel conversion projects to be suitable to retrofit projects type (Fox 2003). Thus, requiring PM practices that support the requirements of fuel conversion projects. The developed PMF creates this structure for executing specifically fuel conversion projects and can help manage the challenges and risks common to retrofit projects. Sanvido & Riggs (1993) and Fox (2003) stated having a diverse and experienced project team for retrofit projects as a success factor. The PMF can provide unexperienced team members the necessary information to execute fuel conversion projects thus, raising their knowledge without having previous hands-on experience of the project type.

5.2 Fuel conversion project management framework development

The company had already executed several fuel conversion projects, but these projects were planned and executed based on the project managers' previous experiences. The way of working of fuel conversion projects had developed over time but still lacked a defined structure of how they were executed. With the increase of fuel conversion projects ordered and in the forecasted pipeline, the department's management saw it as beneficial to develop a structure for execution of fuel conversion projects. Therefore, a PMF was seen as a possibility to create this structure. The second reason behind the PMF was that it could be a tool for the knowledge transfer of fuel conversion projects.

Developing the PMF to be flexible in use was important because of the complexity of fuel conversion projects and the different level of experience among the case department's members. The case company's fuel conversion projects' scope can differ quite much from each other for example, some projects are full scale engineering, procurement, and construction (EPC) contracts and in some only the engineering and procurement is made, in some the logistical scope varies, and so on. Therefore, a rigid methodology could have hindered the effectiveness of the PM more than help it. Kerzner (2010) mentioned that a PM framework can be utilized more freely, and this was the main reason why a framework was chosen over a methodology. Another key benefit of choosing a PMF was the decreased need of training to adopt the framework compared to the required training of a new methodology (Kerzner 2010). This gives the project team members more time to execute projects instead of sacrificing time learning a new methodology.

On one hand, more experienced team members can use the PMF to remind themselves of the main outputs and crucial things to remember or consider. On the other, more unexperienced team members can adapt it more thoroughly to gain understanding of fuel conversion projects, use it as a guiding roadmap in the execution, and to ensure that important activities or processes are not left out. The PMF was not developed to describe every process deeply, be an exhausting list of all the details of the project activities, nor be a handbook for performing fuel conversions. Rather, create a foundational structure for what the main aspects of project execution and key deliverables are of fuel conversion projects.

The framework was developed by methods mentioned in Cohen (2019), Conley (2016), Naybour (2014), and Tonnquist & Holmén (2018). The interviews were conducted to gain insight into the fuel conversion process and develop the information for the framework, like the development process mentioned by Conley (2016). Since the fuel conversion projects naturally had separating main processes it was considered suitable to use stages or in this case phases in the framework to create the main structure of the framework. Adopting stages in frameworks was recommended by Naybour (2014). Additionally, stages are very common in frameworks overall (Tonnquist & Holmén 2018; Garton & McCulloch 2012). Another benefit of the phases was that it made the visualization of the project activities easier and clearer, something recognized in Conley (2016) as well.

The literature indicated that many developed frameworks end up not being used and one of the biggest reasons is the complexity of the framework and difficulty of using it (Tonnquist 2012). Therefore, there was emphasis on describing and visualizing the fuel conversion project process in a simple and easy way. Conley (2016) stated that one of the simplest ways to visualize a framework is using a table. Thus, the PMF uses a table for organizing and summarizing the overall structure and main outputs of fuel conversion projects. The summarizing table was inspired by Trentim (2020) but adapted to represent fuel conversion projects.

However, it was necessary to include a visualization of the project activities as well, to gain better perspective on how the project activities are performed relative to each other and the project timeline, something recommended by Conley (2016). To continue the simplicity, the descriptions of the phases were done using bullet points in the official PMF document. The bullet points make the framework less text heavy and can be used like checklists too. Similarly to Duggan & O'Neil (2013), the need for descriptions in addition to visualizations were realized as important to create a more comprehensive framework. Because the PMF should also facilitate knowledge transfer, only visualizations could not have offered the required depth. Therefore, the descriptions were used to provide more information about the processes and project activities.

The literature indicated that frameworks should include templates, checklists, documents, and other tools which are used in the PM (Tonnqvist & Holmen 2018, Naybour 2014). The PM maturity at the case company is high and several templates, tools and procedures have already been developed. Therefore, a section combining links to the appropriate support functions is included for each phase in the official PMF. Naybour (2014) recommended that documents would be gathered for each phase. By including existing tools and documents, the PMF functions like a collection point for information and knowledge related to fuel conversion projects stored in other places in the case company’s databases. This makes it easier to find the correct information and support tools in a fast way.

To reduce the chance of low usage of the PMF, the feedback workshop was implemented to increase the involvement of the department members in the development. The workshop provided an opportunity for the respondents and the management to validate the correctness of the information in the PMF. In human interaction there is always a possibility that one interprets the other wrong which in this case could have led to the inaccuracies of information in the PMF. The importance of evaluation of a developed framework was pointed out by Naybour (2014). Furthermore, the respondents and management had the possibility to voice their opinion of the framework and provide improvement suggestions. Fortunately, the PMF was proven fairly accurate as there were not huge amounts of interpretation errors. However, improvements were given as well as further information on some of the processes. As a result, the value of the framework increased since the accuracy of information and the usability improved.

5.3 Knowledge transfer of fuel conversion projects

When the case company approached the researcher about the research problem, the department at the case company experienced a challenge that a great deal of the knowledge and experience of the fuel conversion project type was retained by the project managers and engineers that had executed projects like these in the past. However, one vision of the department is that every team member can execute all types of projects the department perform. Therefore, the second research question formed, how can the knowledge of fuel conversion projects be transferred?

Based on the collected data and observations by the researcher it was evident that the department transferred knowledge during collaboration with each other and through more formal events for example, lessons learned workshops that produce codified information. Therefore, knowledge of fuel conversion was available in both tacit and explicit form (North & Kumata 2014). However, the knowledge was mainly transferred through casual discussions and when team members asked each other for support like the knowledge transfer type socialization presented in Nonaka & Takeuchi (1995). This informal knowledge transfer is the most common according to the literature (Davenport & Prusak 1998), so it was not a surprise that this was the main knowledge transfer type at the case department.

While the knowledge was continuously shared through interaction between team members it was hard to share it throughout the department collectively in an efficient way.

To transfer the knowledge effectively for anyone in need, the knowledge had to be transformed into explicit knowledge that would be storable, processable and manageable (North & Kumata 2014).

A PMF was considered as a possible way of transforming the tacit knowledge to explicit, thus enabling the transfer throughout the department in concluded form. This made the framework function similarly to a knowledge market mentioned by North & Kumata (2014). Here, department members who obtain more knowledge of fuel conversion projects can share it to team members in need of it. Similarly, it can function like a database for fuel conversion project specific information which was mentioned as a staple of knowledge management by Disterer (2002), Spalek (2014b), and Wiewiora, Chen, & Trigunarsyah (2010). However, not a database in the traditional sense but rather a collective document of information and links to supporting tools, templates, and material. Therefore, the presented framework is not a static structure but merely a first version. While the maturity of fuel conversion projects increases further, the PMF will evolve simultaneously and may include new objectives, activities, challenges, success factors and so on. Similarly, Tonnquist (2012) and Naybour (2014) also suggested beginning with a simple PMF and updating it once more requirements are identified. Furthermore, the first version is usually not fully developed, and its usability can increase over time.

The PMF includes three of the knowledge transfer types mentioned in Nonaka & Takeuchi (1995). First, knowledge is externalized from turning it from tacit to explicit when it is added to the framework. When the PMF was developed as part of this research the tacit knowledge was gathered with the help of interviews and transformed to text form, thus explicit form. Once the knowledge has been codified into the PMF and a team member utilizes the framework in their work the knowledge is internalized, since it is transformed from explicit form in the PMF to experience and thus absorbed by the team member. Furthermore, the framework also transfers knowledge by combination. Already codified knowledge in other documents for example, lessons learned presentations, emails, manuals, etc. can be inserted into the framework or vice versa and therefore knowledge is transferred by explicitly combining them. However, some of the project activities include the fourth knowledge transfer type socialization since the team member collaborate naturally. An example of this is the lessons learned sharing and discussion of previous fuel conversion projects in the beginning of the initiation phase.

Although the implementation of the developed PMF in practice is limited from this study it is important to note the importance of encouraging team members to update the framework to transfer newly gained knowledge efficiently (Disterer 2002; Spalek 2014b). The framework is only useful if the knowledge in it is relevant and up to date. Therefore, the maintenance of the framework is crucial to not end up useless like many frameworks tend to do (Tonnquist 2012). The project team should be motivated to add new issues that has been identified during project execution so the discovered issues can be implemented or avoided in upcoming projects.

As a result, the developed PMF can be a great tool for transferring the knowledge of fuel conversion projects since it incorporates multiple knowledge transfer types. The comprehensive yet light structure of the PMF allow people with different experience levels to collect the information they need but also update the framework with more knowledge. A benefit of transferring the knowledge in this collective way is it reduces the time required from more experienced team members to instruct less experienced team members on the project type. This can allow more time to project work. In its first version the PMF will transfer the knowledge that has formed from previously executed fuel conversion projects. However, once more fuel conversions are completed the newly gained knowledge can be shared through the PMF to be used in upcoming projects. The PMF also contains project activities that directly encourages knowledge transfer which will most likely result in new knowledge to be formed.

6 Conclusions

The move towards more sustainable fuel sources in electricity production is inevitable as the battle of sustainability and reduction of emissions continues. Instead of building new engine power plants that utilize sustainable fuel sources, existing diesel power plants can be modified to run on these fuel sources through retrofitting the existing application. The research found the modification of existing power plants to create challenges for the PM of these kind of projects. The main challenges affecting fuel conversion projects are, tight schedules, cost deviations, engineering quality, fitment of new design to old designs, material, tool, and site manpower availability, and occurring changes during the project. The results indicated that understanding the scope and requirements thoroughly, collecting accurate information about the existing power plant, and early planning and preparations help to mitigate challenges and achieve success in the projects. The results showed resemblance of challenges and success factors between fuel conversion projects and literature on retrofit projects.

The aim of this research was to study the fuel conversion project process performed by the case company to create a defined structure of the execution of this project type. Based on the current fuel conversion project process, a PMF was developed to create this structure and to support the execution of upcoming fuel conversion projects. The PMF specifies the project delivery of the case company's project model by dividing it into the following phases, *initiation*, *engineering*, *procurement*, *logistics*, and *site works preparations*. The project activities performed in fuel conversion projects are placed in the respective phase they are performed in. The results showed that the phases are not exclusively consecutive but rather overlap each other as some project activities are performed simultaneously. As the PMF represent the project process of fuel conversion projects it naturally answered the first research question. The official PMF delivered to the case company consist of the governing table of the framework seen in figure 8, the visualization of main project activities found in figure 9, descriptions of each phase, challenges and success metrics of fuel conversion projects, and links to supporting tools, templates, and documents.

Only a minority of the members of the case department had experience from past fuel conversion projects. Because of the forecasted increase in number of fuel conversion projects, there was a need to expand the knowledge of fuel conversion project execution throughout the department. The knowledge was mainly tacit as it was bound to the team members who had performed the projects. Therefore, the tacit knowledge had to be made explicit to enable sharing it in a collected way. This made the other objective of the PMF to facilitate knowledge transfer of fuel conversion projects. This is realized by the PMF functioning as a knowledge market where experienced team members can share their knowledge to less experienced ones. This makes it one of the tools the department can utilize for knowledge transfer in combination with the existing discipline tribes, handbook, lessons learned sessions and so on.

A framework was chosen over a methodology to offer flexibility of use. The increased flexibility allows team members to use it how they feel necessary. More experienced team members can use it more freely to support in the execution while less experienced can follow the framework more strictly like a roadmap. The aim is that the PMF will evolve with the maturity of fuel conversion projects, meaning it will be updated once new things about the project type are learned and new knowledge is generated Referring to the second research question, it can be concluded that the developed PMF will support the knowledge transfer of this project type in a flexible and adaptive way.

The research was limited to fuel conversion projects only, even though other project types are part of the case department's portfolio. The research focused on the project delivery part of fuel conversion projects as this is the case departments responsibility. This excluded the sales and warranty phases from the developed PMF. Furthermore, the research was limited to the development of the PMF thus, the implementation of the framework was not included in the research. The retrofit and fuel conversion part of the theoretical framework was challenging to conduct due to the limited number of studies available of these subjects. In addition, it was difficult to decide the level of detail the PMF would describe the fuel conversion projects due to the complexity of the projects.

As this research was conducted on behalf of the case company to support their project management, the PMF was developed to serve their fuel conversion project process. Therefore, it may not be of direct benefit to other studies. However, the research concluded the process of fuel conversion projects, challenges, as well as success factors of fuel conversion projects. These can be beneficial for future research on fuel conversion projects and retrofit projects in general. Furthermore, the use of a PMF as a means of knowledge transfer is an alternative approach which can contribute to new reasons to develop frameworks for project management.

6.1 Suggestions for future research

The research process revealed quite many possible research topics to be studied in the future. First, there seems to be limited studies done on fuel conversion of engine power plants. Here, the performance of the power plant could be studied from a sustainability viewpoint, the realistic costs savings could be argued for, or the technical aspect of the actual fuel conversion process of power plant engines could be studied. Secondly, due to the ongoing sustainability trend, which is important to help the environment, there is a high chance that retrofit of all kinds of entities will increase to battle the construction of new instead of utilizing old. Therefore, the PM of retrofit projects could be studied further. Retrofit PM applying modern PM practices could be studied, even a general PM methodology specially designed for retrofit projects could be developed.

Regarding the developed PMF it could be studied and developed further. The PMF is currently in its first version and focuses solely on the project delivery of fuel conversion projects. Therefore, preparations done prior to the contract being signed could be included as well as the warranty stage. The challenges and risks of fuel conversion projects could be compared to each other giving them risk scores based on their impact on a project. These could be included in the challenges section of the PMF. This way the risks with highest scores could be focused on the most and the severity of newly discovered challenges could be identified. As this research focused on only developing the PMF it did not take the implementation of the framework into account. The literature indicated that the correct implementation of a framework is crucial to its success. Thus, the most optimal implementation process of the developed PMF could be studied to ensure successful integration and maximal usage in the case company PM.

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Appendices

Appendix I. Interview guide

Interview questions:

1. Describe the available processes of fuel conversion projects.
   -starting point from when contract is signed

2. What are the critical factors that need to be considered at the beginning of the project execution phase?

3. What are the critical factors that need to be considered at the product and plant engineering phase?

4. What are the critical factors that need to be considered at the material procurement phase?

5. What are the critical factors that need to be considered at logistics and transportation phase?

6. What are the critical factors that need to be considered at the site execution phase?

7. What are the most critical challenges with the execution of fuel conversion projects?

8. Describe the roles and responsibilities of the project organization for fuel conversions.

9. How is the site organization developed?

10. Is there enough support for the execution of fuel conversions project currently from top management, supporting bodies (e.g., engineering, supply chain), and other support resources (i.e., procedures, processes, systems)? If not, what are the biggest challenges/gaps with respect to such support?

11. How would you define and measure the success of fuel conversion projects?