The trade-off between the 'Traditional' and the 'Modularization & Standardization' business model in the incumbent plant engineering industry

Developing a framework that can help plant engineers in the assessment between staying 'traditional' or going M&S

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October 2015

Master thesis Management of Technology

Faculty of Technology, Policy and Management
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CONFIDENTIAL VERSION

The increasing pressure from low cost competitors and low oil prices have resulted in challenges for the incumbent plant engineering industry such as; the need to reduce costs, the need to speed up development and the need to reduce complexity. For this reason, some of the incumbent plant engineers are considering the potential of the 'modularization and standardization' (M&S) business model in contrast to their current 'stick-built and tailor made' ('traditional') business model. However, the incumbent plant engineers encounter a problem when considering this trade-off; They are unable to make a valid assessment between the two business models. This, in turn, is due to the novel nature of M&S in plant engineering and lack of references. To tackle this problem the author used an extend literature review and a case study to understand what factors and conditions differentiate these two business models. Furthermore, the author used this information to develop a 'pre-assessment' framework that can help the incumbent plant engineers in the assessment to stay with their 'traditional' business model or go for the M&S business model.

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Acknowledgements

This thesis would not have been possible without the time, support and dedication of many people. This section is therefore devoted to giving a special reference, and 'word of thanks', to these people.

At first, I would like to thank the members of the academic community and my graduation committee. A special thanks goes out to my first committee supervisor Rob Stikkelman who continuously supported and advised me during my thesis. I would like to give a special word of gratitude to my graduation professor Alexander Verbraeck who was always spot-on with his tips and advices. Furthermore, I would like to thanks Zenlin Roosenboom-Kwee in specific for her support, especially in the beginning phase of my thesis. Next to this, miss Roosenboom-Kwee also was a good and fun teacher.

Secondly, I would like to thank some of the employees at Technip for making this research project possible. Special thanks goes out to my first company supervisor Nico Steur who was a great sparring partner during my research and awlays had an open mind during discussions. A special word of thanks goes out to my second company supervisor Koos Overwater who's door was always open and who always gave good advices. I would also like to give a special word of gratitude to the Director estimating Ron van West and the Cost estimator Mike Vis for their excellent support during the development of the in depth case study and the Client cost simulation. Furthermore, I would like to mention that my colleagues from the Procurement department were always supportive during my research project and we regularly had a good laugh, thanks for that.

Finally, I would like to say many thanks to all of my family and friends who truly enrich my live. Especially in difficult times my family and friends could always cheer me up and make me feel better. Special thanks goes out to Patricia Boting-Grootenboer which is my biggest Idol in life and on whom I can always fall back. I would also like to thank in specific my father John Boting for his continous mental and financial support during my study period. I would also like to give a special word of gratitude to my girlfriend Lauren van Rijn whos love and support was unprecedented during my research, but also in every other aspect of my live. Furthermore, I would like to thank Petra Stokman, Brenda Dezentjé Hamming-Boting and Maurice Dezentjé Hamming for their interest in my thesis and for them being a listening ear.

The increasing pressure from low cost competitors and low oil prices have resulted in challenges for the incumbent plant engineering industry, such as; the need to reduce costs, the need to speed up development and the need to reduce complexity. For this reason, some of the incumbent plant engineers are considering the potential of the 'modularization and standardization' (M&S) business model in contrast to their current 'stick-built and tailor made' ('traditional') business model. However, the incumbent plant engineers encounter a problem when considering this trade-off; They are unable to make a valid assessment between the two business models. This, in turn, is due to the novel nature of M&S in plant engineering. To tackle this problem the author used an extend literature review and a case study to understand what factors and conditions differentiate these two business models. Furthermore, the author used this information to develop a 'pre-assessment' framework that can help the incumbent plant engineers in the assessment to stay with their 'traditional' business model or put go for the M&S business model.

Executive summary

The incumbent (chemical) plant engineering industry is under pressure for two reasons. At first, the rising internationalization of the economy results in low-cost competitors putting pressure on prices and lead times of projects. Secondly, the decreasing oil prices result in major investment cuts in the oil & gas and chemical industry. As a result, fewer projects are initiated by clients and there is thus increased pressure on the few projects which are available to tender for by the plant engineers. These two pressures result in various challenges for the plant engineer such as; reducing costs, speeding up project development and the reduction of complexity. A potential solution to this problem is the modularization and standardization (M&S) of the plant projects. However, this 'M&S business model' in plant engineering has not really been the topic of research in the academic world. Furthermore, the industry has been experimenting with the M&S business model but did not publish their result due to M&S' strategic significance. Thus, it remains hard for plant engineers to predict or assess whether M&S has potential for them or whether they should stay with their current 'traditional' business model. The aim of this research is therefore to develop a framework that can help plant engineers to assess whether the M&S business model might be relevant for them or whether they should stay with their 'traditional' strategy. The main research problem has resulted in the following main research question:

Under what conditions will the M&S business model, in relation to their ‘traditional’ business model, be of added value in the incumbent plant engineering industry?

In order to answer the main research question an appropriate research approach was determined. The main data sources used are the Literature study and a Case study at Technip. The Literature study is subdivided into two parts the (first) and (second) Literature study. The (first) Literature study focuses more on the creation of a proper conceptual background while the (second) Literature study focuses more on the core of the problem statement. At first, the (first) Literature study is used to collect background information that helps to familiarize the readers with the term used is this research (Chapter 2). Secondly, with the (first) Literature study a relevant theory was found that can be used during analysis to give the readers a more comprehensive and conceptual understanding (Chapter 2). Thirdly, the (second) Literature study was used as general data source to obtain academic and practical literature that differentiates the 'traditional' and M&S business model (Chapter 3). Fourthly, the data from Chapter 3 is analyzed and the relevant information that differentiates the 'traditional' business model from the M&S business model is condensed in a 'list of conditions' (Chapter 4). Fifthly, the Case study will be introduced in Chapter 5, the Case study gives additional information that differentiates the 'traditional' and M&S business model. Sixthly, the data from the case study and expert interviews was analyzed and the information that differentiates the 'traditional' business model from the M&S business model is condensed in a second 'list of conditions' (Chapter 6). Seventhly, the information from the 'list of conditions' (Chapter 4 and 6) was used to create an assessment framework.

The analysis from the (second) Literature study and Case study resulted in a 'list of conditions'. The *'list of conditions'* will be a list of the factors/criteria that differentiate the 'traditional' and M&S business model. The 'list of conditions' is subdivided in *conditions from a plant engineering* perspective and *conditions from a clients perspective*. The conditions of relevance from a plant engineering perspective are; Modularity, Procurement discounts, 'Learning curve' effect, Parallel manufacturing, Using a fabrication yard, Owning a fabrication yard, Standardization, Design variation, Technological improvements, Market segment fit, Plant capacity, Module size and Company commitment. The conditions of relevance from a clients perspective are; Investment costs, Schedule, Energy efficiency and Risk. In the associated chapter it explained exactly why these conditions differentiate the 'traditional' and M&S business model. The conditions that are of relevance from a plant engineering perspective are used to create the assessment framework. The output of the assessment framework can help the plant engineers to decide whether to stay with the 'traditional' business model or to further investigate the M&S business model.

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Chapter 1. Background and introduction

At first, in this chapter the background of the research will be introduced. The background will shortly introduce the motivation for writing this thesis. Secondly, a research problem will be filtered out of the background. Thirdly, from this research problem the author has formulated the associated research questions that can help to structurally solve the problem. Finally, this chapter will indicate the practical and theoretical relevance.

Section 1.1 Background and motivation

The current situation for incumbent plant engineers is dynamic and diverse. Namely, this industry is involved with the engineering, procurement and construction of multimillion dollar projects involving many parties such as the material vendors and construction subcontractors. In addition to this dynamicity and diversity there is strong competition, and customers and investors put pressure on prices (Hicks, Earl, & McGovern, 2000). Furthermore, there are two new trends which have also proven very disadvantageous for the incumbent plant engineers. The first trend is the rising internationalization of the economy resulting in low-cost competitors putting even more pressure on prices and even lead times of projects. The second trend is that of the decreasing oil prices, these decreasing prices result in major investment cuts of large oil and chemical companies. And in turn, these investment cuts eventually mean that fewer projects are being awarded to incumbent plant engineers by clients (Amberg, Gepp, & Horn, 2012). These latter influences result in various challenges for the incumbent plant engineers such as; the need to reduce costs, the need for a shorter time-to-market, and the need to reduce complexity of their work.

A common solutions to this problem is for plant engineers to increase their efficiency. This, however, will not be the topic of discussion in this thesis. A novel opted solution to this challenge is for chemical plant engineers to move away from the 'traditional' (tailor made) plants to 'standardized' plants (Amberg, Gepp, & Horn, 2012) (Gosling & Naim, 2009) (Schaeffler, Vollmar, & Gepp, 2014) (Khomut, Gepp, & Vollmar). In more specific, these authors argue that adding modularization to a standardized plant can augment the benefits of both individual modularization or standardization apart, thereby creating a synergy. This so-called modularization & standardization (M&S) is thus a new potential business model that is claimed to have numerous benefits such as; shorter schedules, less complexity, reduced costs of design, lower risks etc. Not only the plant engineer, but also the client is claimed to reap the benefits of M&S such as less investment costs and earlier start of operation. Not only the academic world but also the plant engineers themselves have been experimenting with the M&S business model (Amberg, Gepp, & Horn, 2012). (Schaeffler, Vollmar, & Gepp, 2014). However, the adoption of the M&S business model is troublesome for plant engineers. According to (Amberg, Gepp, & Horn, 2012) (Schaeffler, Vollmar, & Gepp, 2014) and (Schaeffler, Vollmar, & Gepp, 2014) this is due to the fact that the plant engineers lack the information with which they can make an informed assessment whether M&S is beneficial in their particular case. More evidence for the relevance of this topic is found in the article of (Amberg, Gepp, & Horn, 2012). They argue that in the future a cost-benefit analysis is required to assess and compare the benefits and costs of the 'traditional' business model and M&S business model.

Thus, the plant engineer is unable to properly assess whether changing from 'traditional' to M&S is beneficial for them. This is because the factors that should be taken into consideration in this trade-off are not fully known by the plant engineers and have not been properly researched by the academic world. There is incomplete information about how the client will benefit, or suffer, from an M&S plant, and there is incomplete information on how the plant engineer will benefit, or suffer, from the M&S business model. As example, preliminary information gathering showed that clients rather pay more upfront investment costs for 'over-engineering' to have a more efficient plant, then pay less and have a inefficient plant. Thus, since clients are willing to pay more upfront investment costs the low upfront investment costs, associated with an M&S plant, are not that interesting to clients as some plant engineers might have thought. Furthermore, factors important to only the plant engineer are also not fully know. Preliminary information gathering showed that factors such as market segment fit level of company commitment, the total investment costs, regulation in countries and more are also important to take into account.

Preliminary information gathering thus showed that there is still incomplete information on the conditions that set the M&S business model apart from the 'traditional' business model for incumbent plant engineers. Put differently, there is no holistic picture that shows under what conditions the M&S business model is more beneficial than the 'traditional' business model. This is due to incomplete information on the clients' and plant engineers' enablers, blockers, benefits and costs of an M&S plant in relation to a 'traditional' plant. As a result, it is very difficult to determine whether the switch from the 'traditional' to the M&S business model is right for the incumbent plant engineer. Thus, the knowledge gap is; there is no framework that can be used by the plant engineers that allows them to assess whether the M&S business model is beneficial for them.

To summarize and introduce the problem statement; Increased competition forces plant engineers to reduce costs, lower complexity and shorten the time-to-market. A potential solution that is opted in some literature and experimented with by some plant engineers is to switch from 'traditional tailor made plants' to modular and standard (M&S) plants. However, plant engineers are unable to assess whether the M&S business model is useful or beneficial for them. This research will therefore be dedicated to developing a framework that allows incumbent plant engineers to assess whether the M&S business model is viable for them.

Section 1.3 Research objective

From the knowledge gap the problem statement is brought to light. This problem statement has thought us that the plant engineering industry lacks a framework with which they can make an assessment about the relevance of adopting the M&S business model. By analyzing this problem statement the research objectives or deliverables can be established. The research objective is;

- **To deliver a 'pre-assessment' framework in the form of a set of questions with which the incumbent plant engineers can 'scan', or assess, if the M&S business model is worth further consideration in their particular situation.**

Section 1.4 Research questions

By close investigation of the problem statement and the research objective the research questions can be derived. The research questions will form the guiding line of the research and will guide the data collection and analysis. The main research question is:

- **Under what conditions will the M&S business model, in relation to their 'traditional' business model, be of added value in the incumbent plant engineering industry?**

The sub-research questions are;

1. What relevant information can be found on the incumbent plant engineering industry and their current 'traditional' business model?
2. What is the M&S business model and what role does it have in related industries?
3. What relevant theories can help with answering the research question?
4. What conditions that play a role in the M&S/'traditional' business model trade-off can be found when analyzing the Literature?
5. What conditions that play a role in the M&S/'traditional' business model trade-off can be found when doing a Case study?
6. How can an assessment framework be developed that takes into account all the researched conditions and that can help the incumbent plant engineers in evaluating whether the M&S business model is good option

Section 1.5 Research framework

The research framework is derived in order to let the researcher and readers understand the logic behind the research on a conceptual level. The research framework shows to core of the research problem, what is required to address the problem and what the result will be. Figure 1 gives an indication of the conceptual framework used for this research.

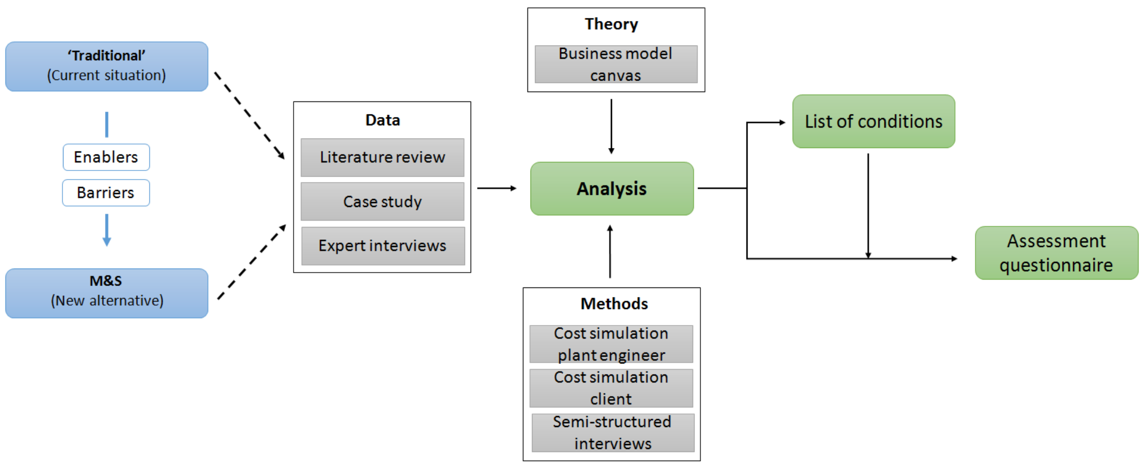

Figure 1: Research framework

It can be found from the research framework that the core of the research problem is the inability to compare the costs, benefits, enablers and blockers of the 'traditional' business model in relation to the M&S business model. Data will be collected via three routes; a literature review, a case study and expert interviews. Several methods are used to obtain data and create data to make it suitable for analysis such as; a cost simulation from a plant engineering and client perspective and a semi-structured interview method. Theory is used as lens to view the data with and to help with easy analysis of the found data. The data is analyzed from which a list of conditions is condensed that are important to take into account in the 'traditional'/M&S business model trade-off. Finally, from the analysis and the conditions the assessment questionnaire is developed which is the main deliverable of this research report.

Research flow

The key to understanding the built-up of this report comes from the research flow. The research flow also increases the replicability of this report and allows other researchers and readers to better understand the logic of this report. Figure 2 gives the visual representation for the research flow behind this report. The research flow shows the main activities, the main deliverables and the sub-research questions addressed per deliverable. The black arrows represent a 'Results in' link, the blue arrows represent a 'followed by' link, the green dashed arrows represent a 'Required for' link and the black dashed arrows simply represent what sub-research questions is addressed for a certain deliverable.

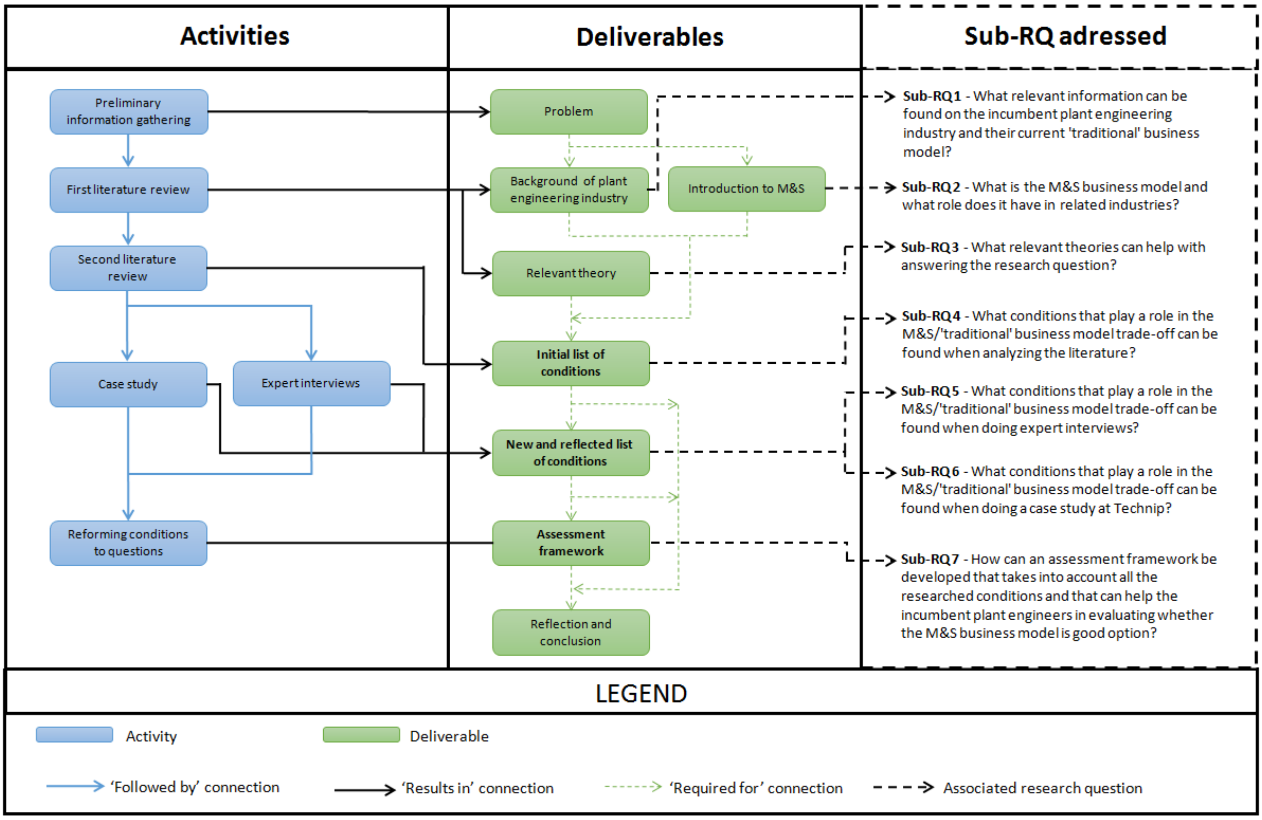

Figure 2: Research flow

Section 1.6 Main deliverables of the research

As can be seen in the Research framework (Figure 1) and Research flow (Figure 2), the main deliverables of this research are the *'list of conditions'* and the *assessment framework*. The *'list of conditions'* are a set of condition which differentiate the 'traditional' business model with the M&S business model in the incumbent plant engineering industry. From the *'list of conditions'* the *assessment framework* was developed. The *assessment framework* is an evaluation tool for incumbent plant engineer to 'quickly' scan whether they should remain with their 'traditional' business model or whether they should maybe go for the M&S business model. The 'road to' the development of the main deliverables is explained below;

The 'list of conditions'

A sub-goal of this research is the development of the *'list of conditions'*. The *'list of conditions'* will be a list of the factors/criteria that differentiate the 'traditional' and M&S business model. And 'differentiating' means; showing the difference in, for example, the; costs, benefits, enablers and barriers the two business models. Two *'lists of conditions'* are formed; (1) The *Initial 'list of conditions'* is formed on the basis of the (second) literature review as data source (Chapter 4) and (2) the *Reflected 'list of conditions'* is formed on the basis of the Case study as data source (Chapter 5). The *Initial 'list of conditions'* introduces only new conditions, the *Reflected 'list of conditions'* reflects on some of the *initial conditions* and also adds new conditions. The *'list of conditions'* will have two purposes. At first, the *'list of conditions'* will be a summary of the literature, case study and interviews on the differences between the 'traditional' and M&S business model in the plant engineering industry. This summary can be used as literature for future researchers engaging in research related to the same topic. Secondly, the *'list of conditions'* will help with the development of the *assessment framework*. More specifically, the *assessment framework* is based on the *'list of conditions'*.

The assessment framework

The selection and development of the *assessment framework* is explained extensively in Chapter 7. For this reason, only small, but on-point, attention will be given to the *assessment framework* in this Chapter. The *'list of conditions'* brings forth a real theoretical input for this thesis on the differentiation between the 'traditional' and M&S business model. With the goal of giving a more practical output from this research, the author developed the *assessment framework*. This *assessment framework* utilizes the information from the *'list of conditions'* (Chapter 5 and 7) and transformed/converted it to an evaluation and/or assessment instrument. The *assessment framework* should serve as 'pre-assessment tool' for incumbent plant engineers to evaluate whether they should stay with their current strategy (i.e. 'traditional') or whether they should put more effort, resources and time in evaluating the 'new' alternative (i.e. the M&S business model). Thus, the *assessment questionnaire* is a 'quick scan' that serves as stepping stone, or first step, to find out if further research towards the viability is needed or not. In order to create such an *assessment framework* several decisions had to be made with regard to the selection of the framework

Selecting a framework

The core of the framework must be based on the collection of data. When selecting an appropriate framework the most important requirements were taken into account. The framework must be (1) easy to use, must be (2) inexpensive to use and should preferably (3) gather as much data from as much people as possible. By reflecting these requirements on different data collection frameworks from (Sekaran & Bougie, 2013), the most appropriate method seemed to be a questionnaire. Thus, the *assessment framework* will be an *assessment questionnaire*.

An assessment questionnaire

Further advice was won with (Sekaran & Bougie, 2013) regarding the further development of the *assessment questionnaire*. There are many types of measurement in a questionnaire (e.g. yes/no, numerical scales etc). However, according to (Sekaran & Bougie, 2013) the most widely used method of measurement is '5 point Likert scale'. This scale is ideal to use since(1) it allows for easy analysis of the results, it (2) offers multiple degrees of freedom to the respondent whilst still (3) making it easy in use.

Dealing with weights

A Caveat during the development of this questionnaire was the weighting of the questions. The information from the (second) literature study and case study was not enough to further development the weights. In addition, the assessment questionnaire needs further validation for adjustment of weights. However, the author did think he had enough information to create at least some form of weights. According to (Ackroyd & Hughes, 1981) a questionnaire can have three types of question; factual questions, perceptual questions and exploratory questions. ***Factual questions*** are either false or true (i.e. descriptive), whereas ***perceptual questions*** can only be agreed or disagreed upon (i.e. normative), *exploratory questions* have no role in this thesis. The ***factual questions*** are given a higher weight since they can be 'tested' on true of falseness, they test the business case objectively. Hence, they have a higher validity. The ***perceptual questions*** have a lower weight since they only reflect the opinions of the employees. The ***perceptual questions*** should be used in case that the ***factual questions*** give a useless result (e.g. a 'tie'). This differentiation between ***factual questions*** and ***perceptual questions*** can be seen as a form of an *initial weighting system*. A system that takes into account the weights *per question* is an activity for that is left to future researchers.

Input and output of the assessment questionnaire

The input for the *assessment questionnaire* are answers to the set of questions by the respondents. The respondents should have a certain background and experience in the plant engineering industry (further explained in Chapter 7). The output of the *factual questionnaire* can be made sense of by checking the respondents answer to every question and reflecting it with the *'initial weighting and classification'* in Appendix E. This *'initial weighting and classification'* shows what answers are positive and what answers are negative for the M&S business model. he output of the *perceptual questionnaire* can be made sense of by checking Appendix F. This Appendix explains when the perceptual questionnaire can be seen as positive for the M&S business model.

Section 1.7 Research design

This section will introduce the research design. The research design will be explained in accordance with the explanation given in (Sekaran & Bougie, 2013). The research design can be seen as the blueprint for the collection, measurement, and analysis of data based on the main research question. Put differently, the research design shows the Nature of the study,

Nature of the study

Referring back to the research question from this thesis *"Under what conditions will the M&S business model, in relation to their 'traditional' business model, be of added value in the incumbent plant engineering industry"* the author finds that the study is partially ***exploratory*** and ***descriptive*** in nature. According to (Sekaran & Bougie, 2013) an *exploratory* study is undertaken when not much is known about a situation. *Exploratory* studies are requires when some facts are known, but more information is needed to develop a viable 'theoretical' framework. Reflecting back on the research question and the general problem statement, the author finds that the *search, or exploration, for relevant conditions differentiating 'traditional' and M&S* makes the study *exploratory* in nature. Furthermore, according to (Sekaran & Bougie, 2013) a *descriptive study* is used to describe a situation as it is. These studies are often designed to collect data that describes the characteristics of events, situation, groups etc. Reflecting back on the research question and the general problem statement, the author finds that *the description of the characteristics of the two business models* makes the study *descriptive* in nature. For this reason, the author concludes that this research leans towards *inductive research* (i.e. forming theory).

The unit of analysis

According to (Sekaran & Bougie, 2013) The unit of analysis refers to the type of population under study. Put differently, the unit of analysis refers to the level of aggregation of the data collected during the analysis stage. Referring back to the core of the problem statement *"Incumbent plant engineering are unable to assess whether the M&S business model has potential or whether the 'traditional' business model is still appropriate"* the author concluded that the unit of analysis is the *business model*. Two types of *business models* - 'traditional' and M&S - will be *explored* and *described* in this research.

Data sources

A part of the research design is the development the appropriate *data sources*, also known as the *research strategies*. This section is devoted to the introduction of and argumentation behind the *data sources* used in this research. Data can be obtained from *primary* or *secondary* sources. *Primary data* refers to information obtained first-hand by the researcher specifically for his research. *Secondary data* reefer to information gathered from sources that already exists. This section will describe what *data sources* are required based on the type and nature of the study. Basically, the data sources describe the sources of the information which can be used to answer the main and sub research questions (Sekaran & Bougie, 2013).

Literature

The first data source is the literature review. Literature provides *secondary data*. As summarized from (Sekaran & Bougie, 2013) literature is defined as; *'The selection of available documents (both published and unpublished) which contains data and information on certain topic expressed from a particular standpoint'*. The literature review has many functions in a research, which also depends on the type of research. However, (Sekaran & Bougie, 2013) distinguish between *four* generic uses of the literature review in research. At first, the literature review can be used to (1) *'narrow down' the broad problem area* and form a final problem statement (i.e. preliminary information gathering). Secondly, the literature review can be used to (2) *develop a conceptual and theoretical background.* Thirdly, the literature review can be used to (3) *develop a theoretical framework and hypothesis* in deductive research. Finally, the literature can be used as (4) *general data source* for the thesis (Sekaran & Bougie, 2013). Overall, the literature can result in both *qualitative* as well as *quantitative* information.

When reflecting the latter points on the research performed in this thesis the following can be said; In this report the author used *preliminary information gathering* to obtain the problem statement and to derive the research objectives and questions (Chapter 1). Next, the author found that is was required to create a *theoretical background* to familiarize the reader with the material (Chapter 2). Furthermore, since this thesis deals with inductive research, no hypothesis were formed, however, a *theoretical framework* was developed via a search of the literature (Chapter 2 - the Business Model Canvas). Finally, literature was also used as *general data source* to partially answer the main research question (Chapter 3). The literature used as *general data source* (Chapter 3) is subdivided in *academic literature* and *practical literature*. The *academic literature* can be seen as scientifically published work and the *practical literature* can be seen as non-published work from companies or conferences etc. The literature in Chapter 3 will be analyzed in Chapter 4 to develop the *'list of conditions'*.

Case study

The second data source that is used is a case study. A case study provides *primary data*. A case study is useful in many situations to contribute to information gathering about individuals, groups, events, organizations etc. (Yin, 2003) defines a case study as an *'empirical inquiry that investigates a contemporary phenomenon within its real-life context using multiple methods of data collection'*. Furthermore, (Yin, 2003) says that case studies are in particular useful for *exploratory* and *descriptive* research. In light of this reasoning, and by reflecting this on the *'nature of the study'* from this thesis, the author finds that a case study is an appropriate data source for this thesis. Furthermore, the relative broad applicability of a case study as data source it another reason for its attractiveness in this research. A case study can result in both *qualitative* as well as *quantitative* information.

Regarding the design of the case study the following can be said. According to (Yin, 2003) a case study can either be a *single-case study* or a *multiple case study*. (Yin, 2003) says that a single-case study can be used when it is a *representative or typical case*. The case company Technip was deemed to be a representative incumbent plant engineering company by the author. For this reason, a *single-case study* was used in this research. Furthermore, within the case study several data sources can be used (e.g. documents, archival records, interview, participant observation etc.). (Yin, 2003) argues that, in order to increase the validity of the case study, as many individual data collection methods as possible should be used. For this reason, the author has chosen to use the following data collection methods within the case study to increase validity;

- In depth case study - Review of *company documents* and, in association with company professionals, the development of cost escalations from a plant engineering view.
- Client cost simulation - A *simulation* of the costs from a clients perspective.
- Expert interviews - *Interviews* with experts from the case company.

These data collection methods are thus part of the case study in this research. They will be further explained in the next paragraph; Methods of data collection. The full case study will be discussed in Chapter 5. The information from the case study will be analyzed in Chapter 6 to form the *Reflected 'list of conditions'.*

Data collection and methods

As can be seen from the previous paragraph two main data sources are used; Literature and a Case study. The *data sources* described what information will be used and what purpose it serves in this thesis. The *methods of data collection* will describe exactly what methods are used and by what means they are analyzed.

Literature review

The first data collection method is the *literature review* and it was used for the Literature data source. A literature review has a 'search', 'evaluation' and 'documentation' phase (Sekaran & Bougie, 2013). The literature in this research consists out of *academic literature* and *practical literature.* The *academic literature* was *searched* for via academic internet databases (e.g. ScienceDirect and Scopus) and was *evaluated* by scanning the abstracts and/or reading the introduction of the articles. The *practical literature* was searched for via conference proceedings or it was found on practical databases. The first search phase was performed for the *preliminary information gathering*. The search on the internet database of ScienceDirect resulted in the first two interesting findings from (Amberg, Gepp, & Horn, 2012) and (Gepp, Vollmar, & Schaeffler, 2014). The search terms used for these findingswere; 'standardization in plant engineering' and 'standardization modularizataion and customization'. After formulation of the final problem statement the the literature was further searched for *background information and relevant theories*. By searching on the internet databases of Scopus and ScienceDirect with the terms 'EPC contractors', 'Plantengineering', 'Engineering, Procurement and Construction' and 'Modularization and Standardization in plant engineering' the relevant articles with background information popped-up (See Chapter 2). Furhtermore, the literature that was used as *general data source* has his own chapter (Chapter 3) devoted to it. This chapter will show the *search* and *evaluation* processes per individual article.

In depth case study

The *in depth case study* is a data collection method that was used for the *case study* data source. According to (Yin, 2003) many methods of data collection can be used during a case study, one of these methods is *review of documentation*. During the *in depth case study* the author has, in collaboration with professional cost estimators, reviewed 'old' (traditional) cost estimating documents and developed a new document in that made the comparison between a 'traditional' and M&S plant. The in depth case study is thus seen as a *review of documentation*. The *in depth case study* is a financial escalation of the costs and revenues of selling a 'traditional' plant compared to the *first* and n^{th} M&S plant. *The assumption of Technip in this in depth case study is that the 'traditional plant is a 'typical traditional plant', for this reason, only one 'traditional' plant was estimated. However, Technip argues that a substantial difference exists between the first and* n^{th} *M&S plant, for this reason, two estimates were developed for the M&S plant (first and* n^{th}*).* Furthermore, the *in depth case study* is substantiated by argumentation from the professional cost estimators explaining exactly why certain costs and revenues differ from each other. The *in depth case study* is introduced in Chapter 5, the results of the *in depth case study* are analyzed in Chapter 6 where the *Reflected 'list of conditions'* is formed.

Client cost simulation

The *client cost simulation* is a data collection method that was used for the *case study* data source. According to (Yin, 2003) a *simulation* is more common in *deductive research*, however, it can definitely be used in *exploratory and inductive research*. The client cost simulation was established after arguments during the interviews in which the interviewees claim that a correlation exists between the capacity of a plant and the importance of the OPEX and the CAPEX to each other. *Thus in a sense this simulation is used in a deductive sense (testing a possible relationship).* In the *Client cost simulation* the a comparison is made between the costs of acquiring and operating (for 20 years) a relatively large and relatively small 'traditional' and M&S plant from a clients perspective. The data that resulted from this simulation is introduced in Chapter 5 and analyzed in Chapter 6 where is used for the *Reflected 'list of conditions'.*

Expert interviews

The *expert interviews* is a data collection method that was used for the *case study* data source. (Yin, 2003) says that *interviews* is a common strategy within case studies to obtain qualitative data. According to (Sekaran & Bougie, 2013) it is possible to choose between unstructured, structured and semi-structured interviews. *Structured interviews* give a fixed and standardized set of closed-questions with little room to deviate for the respondent. In *unstructured interviews* open ended questions are asked to let people just talk about certain constructs and variables. In between both these extremes lies the *semi-structured interview* method. The semi-structured interview delivers a set of structured question, however, the questions are often open ended and can be answered with flexibility. The respondent is allowed to elaborate on certain topics. This might result in new or unknown topics that will be highlighted by the respondent which the interviewer has not thought about before. Since this research has an *exploratory nature* the interview must have some room for the respondent to further elaborate on his topic. However, the precisely demarcated problem area and the descriptive nature of this research requires some structure in the topic. For this reason, the author has chosen to use a semi-structured interview to gain the best of both worlds regarding interviewing techniques. (Powell, 1999) and (Creswell, 2012) say that 5 to 6 interviewees can be deemed as sufficient for interviewees within a case study. For this reason, 5 interviews were held. Furthermore, the data was transcripted and summarized (Appendix A to E). The data from the interviews is placed in Appendix A to E and is analyzed in Chapter 6, where it is used for the *Reflected 'list of conditions'*.

Section 1.8 Relevance of this study

In order to understand how this research can add value there is elaborated on the relevance of the research and the knowledge gap that is should fill. This section will explain how this research will add value in to both the academic world as well as in practice.

Academic relevance

The modularization & standardization (M&S) paradigm originates from the supply chain literature. The supply chain literature defines modularization & standardization as 'forward shifting of the order penetration point' or 'postponement' (Gosling & Naim, 2009) (Donk, 2001) (Olhager, 2003) (Pagh & Cooper, 1998) (Yang, Burns, & Backhouse, 2004) (Zinn & Bowersox, 1988). These authors define 'forward shifting' and 'postponement' as shortening the lead time and increasing the efficiency by doing as much pre-fabrication as possible by either standardizing components and/or modularizing components. A major drawback of these articles is that their scope is limited make-to-order (MTO) industry. The Engineering-to-order (ETO) industry (e.g. the plant engineering industry) has not really been the topic of research regarding 'forward shifting' or 'postponement'. However, some authors (Amberg, Gepp, & Horn, 2012) (Schaeffler, Vollmar, & Gepp, 2014) (Gosling & Naim, 2009) have highlighted the potential benefits of 'forward shifting' and 'postponement' in the plant engineering industry. They argue that the biggest differences between the MTO and ETO industry, regarding the 'forward shifting' strategy, are production volume, product complexity and the customer specificity. Therefore regarding the relevance of this study (Gosling & Naim, 2009) argues that there is the need for research in the costs and benefits of 'forward shifting' in the ETO industry. (Amberg, Gepp, & Horn, 2012) and (Schaeffler, Vollmar, & Gepp, 2014) say that a cost-benefit analysis is needed for the M&S strategy and the 'traditional' strategy of incumbent plant engineers. They argue that it is still unclear what the actual difference benefits and costs are between the M&S strategy and the 'traditional' strategy.

The academic relevance of this study is to develop a 'list of conditions'' that shows the differentiation between the 'traditional' and M&S business model. These conditions can be used for further research to allow other authors to make an actual cost-benefit analysis.

Practical relevance

From preliminary information gathering at the researchers' case company and some from literature practical literature articles (Haney, 2014) (Schulz, 2013) it became clear that incumbent plant engineers are considering modularization and standardization. It became clear that major incumbent plant engineering companies (Fluor, Jacobs, Technip) as well as major energy companies (Shell) are considering M&S as business model for certain technologies. However, no information is released by these companies due to its strategic significance. Some benefits and costs are known for the modularization paradigm, but there is still no way to systematically assess the benefits and costs of modularization and standardization combined for the incumbent plant engineers.

The practical relevance of this study is adding to the practical literature a 'list of conditions' that indicates the differentiation between the 'traditional' and M&S business model. From this list of conditions an *assessment questionnaire* will be developed. The 'list of conditions' and the *assessment questionnaire* can be used by the plant engineer to systematically assess whether the M&S business model is worth further consideration or that their 'traditional' business model is the right approach.

Section 1.9 Structure of the report

The report reads as follows. The current chapter (Chapter 1) serves as the introduction to the research. In this Chapter the reader can find the general problem statement and the associated research questions and objectives required to solve the problem. Furthermore, in Chapter 1 the author laid the foundation of the research approach by mentioning the research framework, type of study, data sources and the methods used in this thesis. Next, in Chapter 2 the author introduces the most relevant background information required and the most important definitions for readers to better understand the research. Furthermore, at the end of Chapter 2 the selection of an appropriate theory for 'easy analysis' for the information found in this research is discussed. Chapter 3 introduces the literature for the analysis to form the 'Initial list of conditions'. This chapter will introduce all the articles used, give a short summary and highlight the material that was used from each article. The articles that are introduced in Chapter 3 are interpreted and analyzed in Chapter 4. This interpretation and analysis will result in the 'Initial list of conditions', which can be found in Chapter 4. Next, in Chapter 5 the Case study will be introduced and discussed. In Chapter 5, the in depth case study and the client cost simulation are introduced. The data found in Chapter 5 will be analyzed and interpreted in Chapter 6. This interpretation and analysis will result in the Reflected 'list of conditions'. Next, Chapter 7 will introduce the assessment framework. The assessment framework will be developed based on the information found in Chapter 4 and 6. Finally, the Chapters 8 and 9 are devoted to the reflection on the research and the conclusions of the research.

Chapter 2. Background and theoretical grounding

This chapter comprises the (first) literature review in which information is gathered that helps readers to become familiar with the topics and terminology. Furthermore, the literature is reviewed to find an appropriate theory that can be used for 'easy analysis'. Thus, this chapter has two main purposes. At first, it the most important background information required to discern the concepts used in this thesis will be discussed. Secondly, the selection and introduction of a useful theory will be discussed

Section 2.1 The incumbent plant engineering industry

The word 'Incumbent' refers to the dominant plant engineers in the market that utilize the 'traditional' operation concept. This thesis will develop a decision/advisory model for the incumbent plant engineering industry. For this reason, it is important to understand the general structure of this plant engineering industry. According to (Schramm, Meisner, & Weidinger, 2010) (Hicks, Earl, & McGovern, 2000) the incumbent plant engineering industry can be classified in the 'capital goods industry'. A characteristic of the capital goods industry is that it provides highly complex and customized products in low-volume on an engineer-to-order (ETO) basis.

As can be seen from figure 3 the incumbent plant engineer is surrounded by three main parties. The client/owner invites several plant engineers to tender for a particular plant. The commercially and technology superior plant engineer is awarded the contract to deliver the Engineering, Procurement and Construction of the plant. The incumbent plant engineers will then design and engineer the plant at their home office. The incumbent plant engineers will outsource the development of the materials (i.e. piping, vessels, valves etc.) and the construction of the materials to vendors and subcontractors respectively (Schramm, Meisner, & Weidinger, 2010).

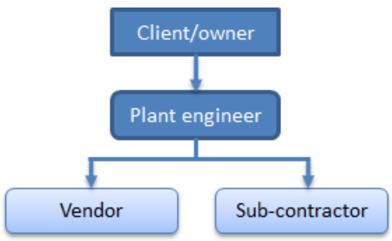

Figure 3: Contract structure for plant engineers (Schramm, Meisner, & Weidinger, 2010)

Engineering, Procurement and Construction (EPC) of 'traditional' plants

Seeing the incumbent plant engineer as a manufacturer products - in their case a production plant (a production plant) - their manufacturing strategy is based on Engineering, Procurement and Construction, or EPC. The incumbent plant engineers are thus responsible for the EPC phase of the project. Figure 4 gives an indication of the working process on the EPC continuum. Every phase can be broken down into several activities (see text below). The EPC continuum starts during the tendering process in which the plant engineer develops his cost estimate and technical specifications and ends when the plant is in operation. The blue boxes above the EPC phases in figure 4 indicate which actor is most dominant in that particular phase (Schramm, Meisner, & Weidinger, 2010) (Hicks, Earl, & McGovern, 2000).

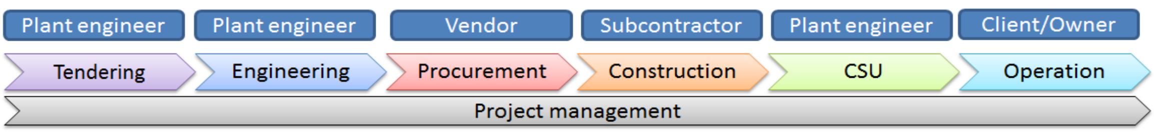

Figure 4: All major phases in work breakdown structure

The EPC phases explained

Below the explanation is given of the sequence of activities that can be expected in the EPC phases of 'traditional' plants built by the incumbent plant engineers (Schramm, Meisner, & Weidinger, 2010) (Hicks, Earl, & McGovern, 2000).

- Tendering – When a plant engineer is invited to tender for a plant he will develop a cost estimate and develop the basic technical specification of the plant. This is actually the first contact that the plant engineer has with the client/owner. The tendering process will give the client an indication what to expect on a commercial and technical basis.
- Engineering – The engineering phase of a traditional plant is characterized by the development of the detailed lay-out and functioning of a plant. Most of the time, a reference plant, similar in scope, is used as a basis to work from. However, much work still needs to be done to ensure the locations' environmental conditions (e.g. product feed, weather, geology etc.) and specific client requirements (e.g. plot lay-out, purity of product, material of equipment etc.) are met.
- Procurement – As the name implies, Procurement involves buying the materials that were defined during the Engineering phase. The procurement phase during a traditional project is characterized by the close interaction with several vendors. Several vendors are allowed to bid on an item and the plant engineer selects the commercially and technically best option. Items with a long lead time are ordered more early during the project, items with shorter lead times are ordered later in the project.
- Construction – Construction refers to the assembly of the separate item from the different vendors into the final plant. For every new plant the incumbent plant engineers select the appropriate subcontractor to execute the construction and installation of the final plant. Construction can take place on-site (i.e. final plant location) or off-site (e.g. in a fabrication yard).
- Commissioning & start-up (CSU) – Once the construction phase has reached the milestone Mechanical Completion (MC), the plant is ready for start-up. This means that the plant will be exposed to extensive testing (e.g. hydro testing for pipes, testing of rotating equipment, emergency shut-down testing etc.). This period of extensive testing should results in the plant being ready for operation.
- Operation – When the plant is ready for operation the plant is handed over to the client/owner. Often still in cooperation with the plant engineer, the client/owner will start-up and ramp-up the plant until it reaches nominal operation. This is a process that can last several months.

Section 2.2 'Traditional' manufacturing strategy definitions

The core of this thesis is to make a comparison between the 'traditional' business model and the M&S business model for plant engineers. This section will therefore explain the most important elements from the 'traditional' manufacturing strategy. A manufacturing strategy is "the process of the point of sales inquiry to delivery of a product to a customer". 'Traditional' refers to the current methods used by the incumbent plant engineers as explained (Amberg, Gepp, & Horn, 2012) (Gepp, Vollmar, & Schaeffler, 2014) (Schramm, Meisner, & Weidinger, 2010) (Azhar, Lukkad, & Ahmad, 2012) and (Schoenborn, 2012). In particular the core concepts of the 'traditional' manufacturing strategy will be introduced. The following definitions and concepts are important and inherent to the 'traditional' manufacturing strategy;

Customization opportunities

Customization opportunities refer to the potential of the client to give input in the process of EPC, with emphasis on the design and engineering. According to (Amberg, Gepp, & Horn, 2012) and (Gepp, Vollmar, & Schaeffler, 2014) clients of incumbent plant engineers often always want to influence the design of a plant. They argue that this is due to the fact that clients want their plant to be perfectly tuned to meet the particular prevailing conditions at their site location. Some of these typical conditions are; minor variations in feed conditions, variations in temperature conditions or particular specification demand for the by(product). By the tuning, or 'over engineering', of these variations the initial investment costs of the clients' plant will increase. However, it is argued that in the long term these costs are recovered due to the lower operational costs borne by the client (Amberg, Gepp, & Horn, 2012) (O'Conner, O'Brien, & Ouk Choi, 2015).

Stick-built approach

Stick-built is a term used in all construction industries. In the plant engineering industry stick-built refers to a situation in which the plant is fully erected on-site (i.e. location where plant will operate). According to (Amberg, Gepp, & Horn, 2012) (Azhar, Lukkad, & Ahmad, 2012) and (O'Conner, O'Brien, & Ouk Choi, 2015) the incumbent plant engineers mostly utilize a stick-built construction strategy. With a stick-built approach the plant engineer orders the materials at vendors, then the vendors ship the materials to the on-site location and the materials are then constructed by subcontractors into the final plant. The stick-built approach is most common in the plant engineering industry, namely, it always works. The authors argue that the stick-built approach can always be used without special consideration and needs, it always fits. Thus, when no agreements are made regarding the construction methods, stick-built is the one-size-fits-all approach.

Modular approach

A competitor of the stick-built approach is the modular approach. A modular approach means that the plant is broken down into smaller components (modules) which together make up the full production plant. (Brookfield & Cooke, 2001) Describe modules as *complete pre-assemblies of equipment bulk materials and components that are fabricated offsite into a steel structure that can be transported and installed at another location*. According to (O'Conner, O'Brien, & Ouk Choi, 2015) (Schoenborn, 2012) and (Azhar, Lukkad, & Ahmad, 2012) the modular approach is used ad hoc by the incumbent plant engineers and can be very beneficial in some situations. However, engaging in a modular approach requires more consideration than the one-size-fits-all 'stick built' approach. The modular approach adds another step the EPC continuum, assembly. In the assembly phase the materials from the vendor are assembled as modules, the modules are then shipped to site where they are constructed into the final plant.

Typical considerations which are made when selecting the *stick-built* or *modular* approach are (Azhar, Lukkad, & Ahmad, 2012);

- Owners' perspective – Owner receptivity on modular construction, the need for expediting (speeding up) the schedule.
- Organizations' readiness – Involvement of top management, the familiarity of the organization with modularity, degree of integration and collaboration with players in the industry, effective communication within organization.
- Design suitability – For some plants it might be too complex to develop modules
- Module related factors – Can the modules be sufficiently structurally stabilized? The local codes and regulation (e.g. distanced between vessels and piping in plants) have to be taken into account. How large will the modules be?

- **Transportation** – Available transportation infrastructure. Can the modules reach site?

Section 2.3 The motivation for Modularization & Standardization (M&S)

The 'traditional' manufacturing strategy is the dominant strategy in the plant engineering industry. However, a few factors resulted in the motivation of plant engineers to become interested in the M&S business model. These are factors that mostly stem from the increasing competitiveness of the industry. Namely, the foremost reasons are the changing competitive landscape leading to cost competition and the need for a shorter time-to-market (Amberg, Gepp, & Horn, 2012). Furthermore, (Hellmuth, Schafller, Gepp, & Vollmar, 2013) indicated that, from all industries, the plant engineering business has relatively low profits in relation to the risk involved. Figure 5 gives an indication of this profit (EBIT) risk trade-off.

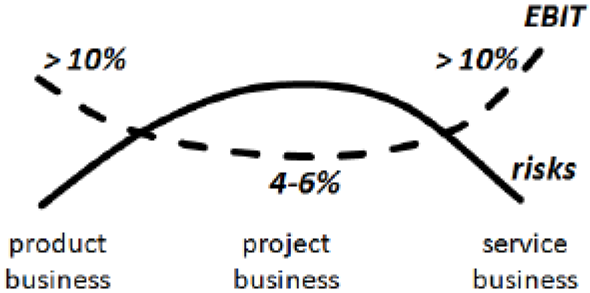

Figure 5: Profit margins in different types of business (Hellmuth, Schafller, Gepp, & Vollmar, 2013)

By decreasing the complexity of the plant many of the above-mentioned issues can be solved. Plant engineers are experimenting with the potential of standardization (O'Conner, O'Brien, & Ouk Choi, 2015). Since an enabler of standardization is modularization both concepts will be used as solutions to this problem. A potential solution is thus the M&S approach.

Theoretical view on M&S

The theory of modularization and standardization stems from production economics and manufacturing strategies. To illustrate, in the work (Hill, 1993) a manufacturing system can be described in the following ways:

- *Make-to-stock* - Finished goods made ahead of demand in line with sales forecasts. Customer orders come from inventory.
- *Assemble-to-order* - Certain components have been made to stock. on receipt of an order the required parts will be assembled to order
- *Make-to-order* - Concerns manufacturing a standard product (customization is nominal and does not increase lead time) on receipt of a customer order.
- *Engineer-to-order* - Custom designs, or changes to standard products, are offered to customers. Lead times include the relevant elements of engineering design and all manufacturing.

Thus, according to (Hill, 1993) every manufacturing company can be classified within these borders. Reflecting this theory on the plant engineering industry it can be found that a plant engineer is classified as an engineer-to-order (ETO) company. In the work of (Olhager, 2003) the theory of (Hill, 1993) is used to explain how and why companies 'shift' between these manufacturing strategies. (Olhager, 2003) argues that every manufacturing strategy is characterized by a distinct Order Penetration Point (OPP). The OPP is traditionally defined as the point in the manufacturing value chain for a product, where the product is linked to a specific customer order (See figure 6). Put differently, the OPP is where the *push* and *pull* elements of the supply chain meet.

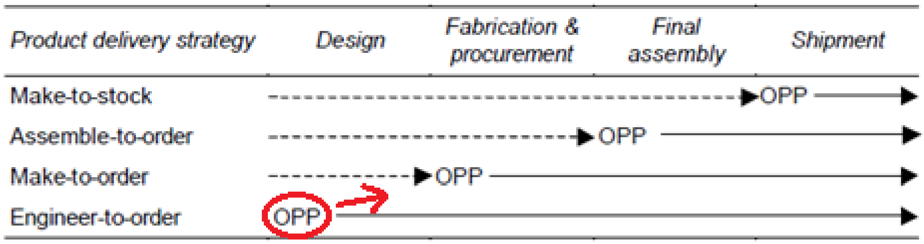

Figure 6: The relationship between Manufacturing strategies and the OPP (Olhager, 2003)

Thus, when reviewing how modularization & standardization (M&S) in the plant engineering industry will reflect on this theory (figure 6), the following can be concluded: When a plant engineer applies M&S it will no longer 'design' the plant, this means that the OPP 'shifts' up and to the right (See figure 6). As example, the ‘traditional’ and ‘modular’ manufacturing strategies are both ETO strategies with their OPP in the Design phase.

Examples of M&S in the engineer-to-order industry

The concept of modularization & standardization in the general engineer-to-order industry is not new. As already explained, the plant engineering industry indeed already applies modularization. However, the standardization element is new (Karim & Nekoufar, 2012) Says the following about standardization in plant engineering; *“Standardization in practice means uniformity in all plant layouts, general arrangements, general assembly, calculations, technical specifications, enquiries and all main construction drawings and documents as far as possible using a standard project of the same capacity and product specification. Although some design depends on the site's geographic location and available raw material.”*

The shipbuilding industry – a typical engineer-to-order business – leads the way to simultaneously modularizing and standardizing designs for engineer-to-order companies. Figure 7 gives an indication of the current status in the industry regarding the appliance of modularity and standardization. From this graph it becomes clear that certain housing infrastructures are more standard built and chemical production facilities more modular built. Furthermore, it is found that auto-manufacturing is very far in modularizing and standardizing the design.

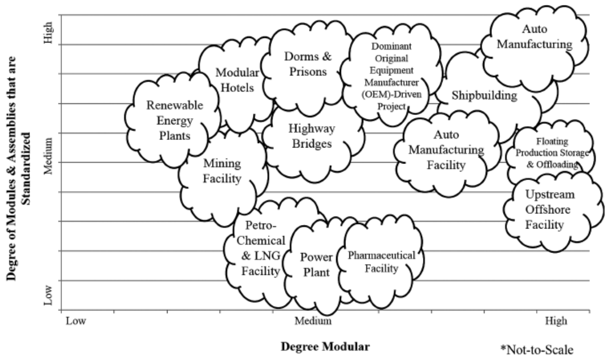

Figure 7: Modularization vs. standardization across industries (O'Conner, O'Brien, & Ouk Choi, 2015)

Section 2.4 The Business Model Canvas

This chapter is devoted to the selection and explanation of a relevant theory that can be used as 'lens' to view the research with and help with 'easy' analysis. To understand what theory might be useful the core of the problem and the required perspective should be known. The problem in this research is about understanding the difference between two business models. From the background in this chapter it becomes clear that the difference between the 'traditional' and M&S

business model is largely characterized by different strategies, different activities, different supply chain structures, and in general how a business is organized. *For this reason, an appropriate theory for this research is one that can help to analyze data from a strategic business and economical perspective.* The theory should help in mapping the differences between the business models.

theories and models that might be useful for analysis of business strategies, business models and business economics are; Porters Five Forces model, SWOT (Strengths Weaknesses Opportunities and Threats) analysis and the Business Model Canvas (BMS). All models can be used for analysis of the business on strategic level. However, the author found that the BMC was most appropriate for this thesis since it is very practical in use and is the is a good theory for direct comparison of Business Models (Morris, Schindehutte, & Allen, 2002).

At first it is important to understand that the term 'Business Model' means different things to different people. In general, words like; business model, strategy, business concept, revenue model and economic model are often used interchangeably (Morris, Schindehutte, & Allen, 2002). However, in this research the term business model refers to the definition of (Ostwalder, Pigneur, & Smith, 2010).

"the rationale of how an organization creates, delivers and captures value"

The BMC is a well known and often used framework to analyze business models of companies and is developed by (Ostwalder, Pigneur, & Smith, 2010). In addition, the BMC is used to; clarify the current business model of a business and make it easier to compare different business models. Furthermore, the BMC subdivides a business model into four main areas Customers (blue), Offering (Green), Infrastructure (Red) and Finances (Yellow). These areas can be further subdivided into 9 components. Figure 8, shows the BMC framework.

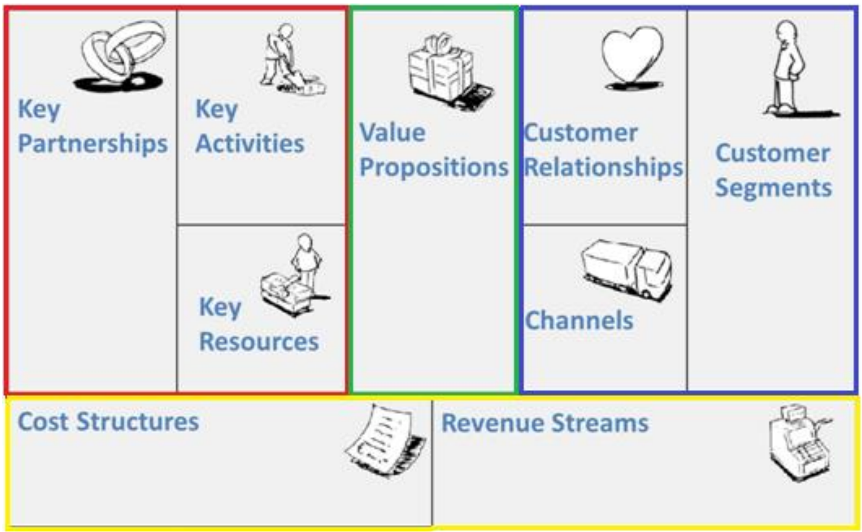

Figure 8: The BMC framework (Ostwalder, Pigneur, & Smith, 2010)

The BMC is useful for two reasons. At first, since the research objective is about comparing the 'traditional' plant engineering business model with the 'new' M&S business model the BCM can prove beneficial. Secondly, the BMC can be useful because it offers a classification that allows the business model to be analyzed in more manageable pieces. Furthermore, in the BMC general terms are used that can help with clarification of the research.

Infrastructure

The infrastructure area in the BCM describes the most important activities, resources and partnerships a company has with which it creates the value of the business model.

- The *Key activities* describe the most important things company must do to make their business model work. The *Key activities* help to create the value proposition. Typical *Key activities* are production activities (e.g. Production (i.e. designing, making and delivering a product), problem solving (i.e. coming up with new solutions) and platform/network (i.e. managing a platform, managing networks).
- The *Key resources* describe the most important assets required to make a business model work. The *Key resources* help to create the value proposition. Typical *Key resources* are physical (i.e. buildings, machines, vehicles etc.), intellectual (i.e. brands, proprietary knowledge, patents, partnerships etc.), Human (i.e. tacit human knowledge) and Financial (i.e. financial resources and financial guarantees).
- The *Key partnerships* describe the network of suppliers and partners that make the business model work. In the BMC there is distinguished between four types; strategic alliances between non-competitors, partnerships between competitors (coopetition), joint ventures to develop new business, and buyer-supplier relationships to assure reliable suppliers. *Key partnerships* are formed to; optimize the economies of scale, reduce risk, reduce uncertainty or to acquire typical resources.

Offering

What attracts a client to a company? What does client want in exchange for his money? These are questions that are directly related to the offering from according to the BMC. The offerings can either have a basis in a quantitative (e.g. price and efficiency) manner or qualitative (e.g. customer experience) manner. The offering frame has one component in the BMC, the value proposition;

- The *Value proposition* of a company describes the products and/or services it offers to the client and what actual value or benefit is delivers to them. Put differently, the *Value proposition* is the reason why a customer turns to a particular company; it is the 'bundle of benefits' it offers to a customer. Typically value propositions vary on; newness, performance, customization, 'getting the job done', design, status, price, cost reduction, risk reduction, accessibility and convenience.

Customers

Which customers and/or markets should be targeted by a company with its offering? That is an important question for the Customer frame from the BMC. The customer area can be subdivided into; Customer segments, Customer relationships and Channels.

- The *Customer segment* is referred to as the heart of the business model in the BMC; namely, without customers no business. In order to better fit the offering to a customer they are grouped into segments. Once the *Customer segment* is defined the business model is designed around it. The BMC discerns between the following general *Customer segments*; Mass market (i.e. components of business model not fine-tuned), niche market (i.e. business model focus on particular segment), segmented (i.e. segmentation within a particular segment), diversified (i.e. serving unrelated segments) and multi-sided (i.e. serving mutually dependent customers in particular market segment).
- The *Customer relationship* describes the type of relationship that a company establishes with specific customer segments. The type of relationship a company chooses might be driven by the following motivations; customer acquisition, customer retention or boosting sales.

- The *Channels* describe how a company will communicate and reach the customer segments to deliver their value propositions. The channels are the points of interaction between company and customer due to communication, distribution and sale channels. There are five channels types; sales force, web sales, own stores, partner stores and the wholesaler. There are five channel phases; awareness, evaluation, purchase, delivery and after sales.

Financials
Parallel to all the areas of the BCM, and the basis of a company's financial viability, is the 'Finances' area. This area should explain how a business spends and makes money. The area is subdivided into Cost structure and Revenue streams.

- The *Cost structure* should describe all the costs incurred to operate a business model. Developing and delivering value, maintaining relationships and generating revenue all incur costs. The Cost-structure of a business model can be generally subdivided into two extremes; Cost-driven and Value-driven. Furthermore, these structures can have the following characteristics; fixed costs (i.e. do not vary with production output), variable costs (i.e. vary with production output), economies of scale (i.e. cost advantages due to larger output), economies of scope (i.e. cost advantages due to a larger scope of operations).
- The *revenue structure* represents the cash a company generates. The different revenue streams which can be differentiated among are; Asset sale (i.e. selling the ownership right of a physical product), Usage fee (i.e. the more service is used the more one pays), Subscription fees (i.e. selling continuous access to a service), lending (i.e. temporarily granting someone exclusive rights) and licensing (i.e. permission to use protected intellectual property rights), brokerage fees (i.e. fees collected when serving as intermediary) and advertising (i.e. fees for advertising. Revenue streams are either transactional (i.e. one-time payments) or recurring (i.e. ongoing payments).

Logic of using the Business Model Canvas (BMC) theory
The BMC theory will be used as lens to view the findings with. By applying this theory a comprehensive and conceptual understanding is offered to the readers and the future researchers in this topic. Furthermore, the BMC will also offer a 'simplified' framework is offered for further analysis in this research (e.g. for developing the *assessment questionnaire*).

Chapter 3. The (second) literature review

The first data collection method is the literature review. Logically, a literature review was also used as data collection method for obtaining the full problem statement, background and theoretical grounding (The first literature review). However this (second) literature review is used as general data source to obtain information that can help in differentiating between the 'traditional' and M&S business model. The (second) literature review subdivides the literature into academic articles and practical articles. Academic articles are distinguished as articles that are published in scientific databases. Practical articles are distinguished as articles that have more practical value and come from conferences, from best practices, or are developed as in-house information source from industrial companies. This chapter will introduce the (Second) literature review, the methods of collecting the literature and the scope of the literature.

Section 3.1 Scope of the (second) literature review

The second literature review is different from the first literature review (Chapter 2), in that this literature review will be very much focused on the core of the research problem, that is; finding the differences between the 'traditional' and M&S business model. The scope of this literature research is the plant engineering industry and the construction industry. The construction industry was involved because there simply are very little articles regarding only the plant engineering industry. The construction industry also operated on an EPC basis and the method of operation is thus very similar. Furthermore, articles that compare 'traditional' and 'modular' (that is without the standardization element) are also taken into account due to the lack of relevant articles. Two types of literature are used; (1) literature from academic sources and (2) literature from practical sources. The following section will discuss what articles were used, how they were found and why they are interesting for this thesis.

Section 3.2 Literature from academic sources

The relevant academic literature is scarce on this topic. Even though engineering companies have been experimenting M&S they did not publish the results since it has strategic purposes (Amberg, Gepp, & Horn, 2012). Academic literature on this topic can be generally classified as (1) explorative (what motivation do companies have to use M&S) and (2) descriptive (e.g. analyzing and describing the costs and benefits of M&S). The authors (Amberg, Gepp, & Horn, 2012) (Hellmuth, Schafller, Gepp, & Vollmar, 2013) and (Khomut, Gepp, & Vollmar) were the articles found regarding the explorative part of the 'traditional' versus M&S. These articles were are relevant for the introduction of this report but are not interesting for further analysis.

The descriptive part of the literature is the material which can truly help in answering the main research question. This literature describes the difference in costs, benefits, enablers and blockers between the 'traditional' and M&S business model. These articles were found by searching profound academic databases (e.g. Scopus and Science direct) with search terms as; modularization & standardization, plant engineering, standardization vs. customization etc. The most important and relevant articles that were found, including the specifics on where to find them, are briefly introduced below;

Standardization Strategy for Modular Industrial Plants, by (O'Conner, O'Brien, & Ouk Choi, 2015)

This article was found on Scopus by searching on the terms; modular standard plants. This is a very recent article that is exactly in the right domain (plant engineering) and has the exactly right topic (modularization and standardization versus customization and stick-built). This article discusses what 'modularization and standardization' combined means in the plant engineering industry, who currently uses it and what its economic advantages and disadvantages are in relation to the 'traditional' method. The research method was an extensive literature review and a case study at 8 plant engineering businesses. The article claims that 21 experienced construction professionals and experts have taken part in their research to regularly brainstorm and discuss the results.

Exactly what information will be used from this literature for analysis is the following: The extensive list of advantages and disadvantages, condensed in 10 major benefit items and 3 major cost items, was used in this research. The major benefits that will be analyzed further on in this research are; reuse potential, design and procure in advance, procurement discounts, parallel engineering, learning curve benefits in several EPC phases and maintenance cost savings. The major costs that will be analyzed further on in this research are; marketing costs, cost of establishing the standard and sacrificed flexibility.

Modular v. Stick-Built Construction: Identification of Critical Decision-Making Factors, by (Azhar, Lukkad, & Ahmad, 2012)

This article was found via the Associated schools of Construction website searching on term like; ‘modular vs. stick-built’ and ‘engineering, procurement and construction’. This article focuses on the comparison between 'modular' and 'stick-built' construction methods in the civil construction industry. The authors argue that the lack of decision making expertise in the construction industry is the only reason why 'stick-built' is always chosen, it simply always fits. This research can be useful since it builds on this latter problem by researching what the critical decision making factors are for choosing either 'modular' or 'stick-built' construction approach. This research method used in this article is a literature review combined with a questionnaire and a focus group to slim the result down.

Exactly what information will be used from this literature for analysis is the following: The authors from this article identified the most important decision making factors that have to be taken into account in this research. These decision making factors represent potential enablers and blockers that are also useful for this research. These decision making factors that will be used for further analysis were; suitability of process design, structural steel requirements for modules, accessibility of the on-site location, labor availability, available transportation infrastructure and the readiness of the plant engineering organization.

Saving time and money on major projects, by (Hart, Phaf, & Vermeltfoort, 2013)

This article was found via a link on Scopus leading to the McKinsey Oil & Gas Practice. Search terms used were ‘standardization modularization plant engineering’ and 'Chemical industry'. In this article the authors argue that due to the spiraling development costs for plant engineers there will be increasing strain on their ability to earn adequate returns. The authors further argue what strategies might be applied to counteract these developments. This article is useful since it elaborates on the modularization and standardization paradigm as counterstrategy. In the article there is made use of a the internal database from McKinsey & Co.

Exactly what information will be used from this literature for analysis is the following: The article gives advice to plant engineers on dealing with the switch from their 'traditional' strategy to the M&S strategy. What is useful in particular are the enablers of standardization which elaborated and the importance of corporate commitment which is elaborated on. Further information from this article that is used is the information that deals with the learning curve of standardization.

Standardization of steel plant building in a portfolio of projects, by (Karim & Nekoufar, 2012)
This article was found via Scopus with a link that redirected to the Steel times international Journal. The search terms used were 'standardization' and 'plant engineering'. This article is useful for this research because the main topic focuses the relevance of standardization in the EPC of steel plants and its contrast to the current 'tailor made' approach. These EPC of steel plants is deemed to be similar to building chemical or petrochemical plants. The article argues that the 'traditional' method of operation is too complex, requires too much time and has many contingencies. The article further elaborates on the potential to use a standard approach in plant building as 'solution' to the problems from the 'traditional' approach. The authors introduce the requirements, enablers and blockers of introducing a ‘standard’ plant as new business model in contrast to the traditional business model. The research method used in this article is a literature review.

Exactly what information will be used from this literature for analysis is the following: The article explains and elaborates on typical benefits such; shorter schedules, cost savings, improved quality and experience build-up. Furthermore, the article introduces some of the potential enablers of standardization in plant projects such as; the importance of strategic management and the importance of company commitment.

Engineering reuse, modularization and standardization in plant and systems engineering, by (Verlag, 2004)
This article was found on Scopus with a link direct to the Digital Plant Engineering Journal. The search terms that were used and resulted in this finding were; ‘repeat work’, ‘modularization’ ‘standardization’ and ‘plant engineering’. This article is useful for this research because it focus on the contrast between the 'traditional' and M&S paradigm in the steel plant engineering industry. The authors argue that the M&S concept has proven very beneficial in some other ‘capital intensive industries’ such as automotive, aeronautical and mechanical. However, the development of M&S in chemical plant engineering stays behind. They argue that the low volume of production and the complexity of functional requirements in plats are major contributors to this lacking. By using some case studies in from ‘power plant engineering’ the author induces the factors which are imperative to take into account when switching from the ‘traditional’ business model to the M&S business model in plant engineering.

Exactly what information will be used from this literature for analysis is the following: At first, this article is relevant because discuses some of the blockers for the adoption of the M&S paradigm such as; the low production volume in plant engineering and the complexity of the product. Furthermore, this article is used for the benefits of M&S that is discusses such as; the potential to offer lower investment costs to the client and the potential to built a learning curve. In addition, the article touches upon some of the costs of using the M&S business model, such as; the costs when there is a need to apply variation in the M&S design and the costs of fitting the M&S product in the right market and customer segment.

Section 3.3 Literature from practical sources

Just like the academic literature the practical literature on the topic of this research is scarce. One academic article (Amberg, Gepp, & Horn, 2012) claim that, even though some major plant engineers and oil & energy companies have been experimenting with M&S, they do not publish the results due to its strategic significance. However, some practical literature was found that either (1) discussed the benefits and costs of the modularization approach in relation to stick-built approach

(Kalilec, 2005) (Redmon, 2006) (Schoenborn, 2012) (Brookfield & Cooke, 2001), (2) discussed the benefits, costs and enablers of standardization in the plant engineering industry (Haney, 2014) (Meyer, 2007), or (3) literature that gave a comparison between current and best practices regarding modular approach in relation to the 'traditional' approach (West, 2011). All the articles were descriptive in nature and the results that were found in the articles are based on practical experience.

These practical literature articles were found by searching internal sources at the researchers case company Technip. These internal resources are mostly experienced engineers within Technip. They obtain this articles either at conferences or via their network connection in the industry.

Modular Fabrication in the Resources Sector in Western Australia: Current Practices and Strategies for Improvement by (West, 2011)

This article was obtained from the personal database of an experienced project manager at Technip. This article discusses the current practices used for modular construction in the chemical engineering industry. Furthermore, it discusses how the current practices can be improved by offering some strategies for improvement. Of relevance for this research are the advantages and disadvantages of modularization in relation to the 'traditional' stick-built method and the success factors of modularization. The findings in this report were obtained through face-to-face interviews with experienced engineering firms from Australia.

Exactly what information will be used from this literature for analysis is the following: The article discusses advantages of modularization in relation to the 'traditional' approach to be; reduction in costs, reduction in schedule and improved risk management. The article discusses the disadvantages associated with modularization in relation to the 'traditional' approach to be; higher steel cost, higher transport cost, higher engineering cost, increased coordination efforts, varying quality and increased installation costs. Furthermore, some success factors were also highlights which also might be relevant for this research, they are; preferred supplier arrangements, vertical integration, government policies and available infrastructure. The above-mentioned topics will be further analyzed later on in this research.

A Case Study Approach to Identifying the Constraints and Barriers to Design Innovation for Modular Construction by (Schoenborn, 2012)

This article was handed out by an experienced professional construction engineer from Technip. The article discusses the barriers and constraints when applying a modular approach in the design for homes in relation to a stick-built approach. This article is not aimed at the plant engineering industry but since the basics of construction remain similar among the industries some elements might from this article might be generelizable also to the plant engineering industry. This article introduces a general literature review in which it explains definitions used in construction, sums up the benefits of modularization in relation to stick-built and highlights some other current trends in construction. Furthermore, this article uses a case study to tests its findings from the literature review via questionnaires at five different companies.

Exactly what information will be used from this literature for analysis is the following: The literature study from this article introduced the perceived benefits and challenges of modularization in relation to the stick-built approach. Some 'perceived benefits' that were explicitly discussed in this study will be used for analysis in this research. The 'perceived benefits' that were discussed are; reduced construction time, increased quality, increased productivity, increased safety, reduced construction risk and less environmental impact. Some challenges for the trade-off between modularization or stick-built that were discussed in this article will also be used for analysis in this research. The challenges that were discussed are; increased planning efforts, increased coordination during projects, transportation cost increase, less flexibility in design changes, procurement. The above-mentioned topics will be further analyzed later on in this research.

Meeting energy demand with off-site modularization by (Redmon, 2006)
This article was found during the scanning the web for practical sources, it was eventually found on the website of CB&I (A major incumbent plant engineer). In this article it is argued that continuous growth for energy requires plant engineers deliver plants faster than how they currently operate (stick-built). The article therefore discusses how modularization can offer benefits but also what costs it has in relation to the stick-built approach. The article discusses the advantages and disadvantages of modularization and the critical success factors for modularization. The article was written by John Redmon, a senior operations manager with nearly 40 years experience.

Exactly what information will be used from this literature for analysis is the following: The article discusses the advantages and disadvantages of modularization in relation to the 'traditional' stick-built approach which will be useful information for this research. In the article the following advantages are disused; the potential to work in a controlled environment (fabrication shop), better quality control resulting in a better quality product and less safety risk. The article argues that the disadvantages are local labor regulations and the space available for the cranes to place the modules. Furthermore, in the article there is elaborated on the criteria that have to be taken in to account when evaluating modularization, these are; equipment size, maintenance access and the ability to incorporate piping and electrical systems in the modules. The above-mentioned topics will be further analyzed later on in this research.

Foster Wheeler modularization by (Meyer, 2007)
This is a PowerPoint slide pack from a process industry congress on modularization by Foster Wheeler (A major incumbent plant engineer). The slide pack was obtained via a professional construction engineer. This slide pack from foster wheeler summarizes their experiences from the use of modularization in relation to the more common 'stick built' approach. The slide pack is useful for this research since it compares the cost upsides and downsides of the modularization approach in relation to the stick-built approach. The slide pack also elaborates on some of the drivers for choosing modularization.

Exactly what information will be used from this literature for analysis is the following: The slide pack elaborates on the cost upsides from modularization; less site attribute cost when building fabrication yard, higher productivity when building in fabrication yard, reduced schedule and higher NPV for client when he can produce earlier. Furthermore, the cost downsides will also be used, these are; increased cost of structural steel, increased cost of transport, increased cost of engineering. Overall, it is argued in this slide pack that Foster Wheelers main driver for modularization is always reduction of schedule time but that this mostly comes at a higher cost.

Feedback Air Products on Modularization Approach for Petroplus Cressier Project by (Kalilec, 2005)
This is a PowerPoint slide pack obtained from Technip database regarding feedback on projects. It is a short slide pack which summarizes the advantages found for that particular project. This

slide pack can be useful for this research since it compares the stick-built construction with the modular construction method.

Exactly what information will be used from this literature for analysis is the following: The slide pack elaborates on the potential advantages of using a fabrication shop in relation to on-site work, it discusses the nature of schedule advantages of modularization, safety advantages, efficiency advantages and commercial advantages.

EPFC solutions, maximize modularization by (Haney, 2014)
This article was obtained surfing the web for major conferences and summits regarding plant engineering and EPC contracting. This article was found on the website of the Modularization and Off-site Construction summit in 2014. This article is written by Fred Haney , an executive director and subject matter expert for modularization and standardization in plant engineering at Fluor (major incumbent plant engineer). In his article he promotes the future use of standardization combined with modularization. This article is interesting for this research since (Haney, 2014) elaborates on the drivers, advantages and risks of a modular and standard approach in relation to the current 'traditional' approach.

Exactly what information will be used from this literature for analysis is the following: This article is especially handy since it truly elaborates on how modularization and standardization have a synergy. The article further elaborates on the what and why the drivers are to choose the M&S approach, such as; lower total cost, shorter construction schedules, reduced safety and quality. Finally, another relevant element taken into account for this research are the risks when using a modular and standard approach. The article elaborates on some risks such as; modularization strategy developed too late, modules incomplete at shipment and transportation risks.

Modularization of LNG liquefaction plants by (Brookfield & Cooke, 2001)
Modularization and standardization is applied by some companies in the LNG process segment (MacDonald, 2013). For this reason, the web was scanned on how the M&S paradigm in the LNG process industry could help for this research. Eventually, this article as found via the LNG journal website. This article will be useful in this research since it contrasts the drivers of the 'modular and standard' approach in relation to the 'customized and stick-built' approach. This article is deemed valid and reliable since it was written by an experienced Director and Project Operation Vice President from Foster Wheeler.

Exactly what information will be used from this literature for analysis is the following: The argues that certain drivers have to be taken into account when considering the M&S approach such as; the importance of a shorter schedule?, how safe is the on-site location?, is there enough labor available on the on-site location? and can you use a fabrication shop to built the modules?

Section 3.4 Summary of literature used

This section introduces the summary of the literature articles used for this research. The literature is divided into academic quality articles and practical quality articles. Table 1 introduces the title, author and the formation used from the articles.

Table 1: Summary of literature articles

Title	Author(s)	Information useful
Academic literature		
Title	Author(s)	Information useful
Standardization Strategy for Modular Industrial Plants	(O'Conner, O'Brien, & Ouk Choi, 2015)	List of economic advantages and disadvantages of M&S in chemical plant engineering industry
Modular v. Stick-Built Construction: Identification of Critical Decision-Making Factors	(Azhar, Lukkad, & Ahmad, 2012)	The enablers and blockers discuses for the switch between 'traditional' and M&S
Saving time and money on major projects	(Hart, Phaf, & Vermeltfoort, 2013)	The benefits and costs of M&S and also and some enablers when choosing M&S.
Standardization of steel plant building in a portfolio of project	(Karim & Nekoufar, 2012)	What factors to take into account when switching from 'traditional' to M&S; what are the enablers, what are the blockers etc.
Engineering reuse, modularization and standardization in plant and systems engineering,	(Verlag, 2004)	The blockers of switching from 'traditional' to M&S and the benefits and costs that can occur with the M&S business model
Practical literature		
Title	Author(s)	Information useful
Modular Fabrication in the Resources Sector in Western Australia: Current Practices and Strategies for Improvement	(West, 2011)	The listed advantages and disadvantages of modular approach in relation to 'traditional' approach and some success factors, or enablers, when switching to the modular approach.
A Case Study Approach to Identifying the Constraints and Barriers to Design Innovation for Modular Construction	(Schoenborn, 2012)	The perceived benefits and costs of modular construction in contrast to stick-built and the challenged that occur when switching to this type of construction.
Meeting energy demand with off-site modularization	(Redmon, 2006)	The costs and benefits of a modular plant in relation to a stick-built plant
Foster Wheeler modularization	(Meyer, 2007)	The cost upsides and downsides of a modular plant in relation to stick-built plant
Feedback Air Products on Modularization Approach for Petroplus Cressier Project	(Kalilec, 2005)	The advantages of working in a fabrication yard (only for modular plants) in relation to working on-site.
EPFC solutions, maximize modularization	(Haney, 2014)	The argumentations on the synergy between modularization and standardization. The drivers and risks introduced for the M&S approach.
Modularization of LNG liquefaction plants	(Brookfield & Cooke, 2001)	The drivers for choosing the M&S approach.

Section 3.5 Reflection on (second) literature study

From the (second) literature study it became clear that the topic of modularization and standardization is novel in the plant engineering industry. Namely, not many articles are published that deal with M&S, and the trade-off with a 'traditional' business model, in the plant engineering domain. For this reason, this research can be useful in the future to help researchers that are exploring the benefits, costs, enabler and costs M&S for plant engineering.

Regarding the literature study of academic articles the researcher has found that there is only one relevant article that has the right topic and the right domain (O'Conner, O'Brien, & Ouk Choi, 2015). Other articles did have the right topic (comparison of 'traditional' and M&S) but had different domains (e.g. steel industry, power plant industry or civil construction industry). However, since these domains are very similar to the plant engineering industry it is deemed that the information from those articles are relevant to use for this research. In general, the academic literature review has mostly resulted in the costs and benefits of M&S in relation to the 'traditional' business model and also some of the enablers and blockers when switching between the business models.

Regarding the literature study of practical articles the researcher has found that there are much articles discussing the trade-off between modular and stick-built but there are fewer articles that take the standardization element into account. However, two reliable practical articles (and one academic article (O'Conner, O'Brien, & Ouk Choi, 2015)) were found (Haney, 2014) (West, 2011) in which it is argued that standardization and modularization augment each other's benefits. However, the practical article all had the right domain (plant engineering industry). In general, the practical literature resulted in finding the difference in costs and benefits between a modular and stick-built plant, which is deemed to resemble the M&S / 'traditional' trade-off. However, some articles did highlight the benefits and costs of an M&S plant.

To summarize, the researchers finds that with this literature study he has found sufficient evidence which can be used for analyses and to answer the fourth sub research question; *What conditions that play a role in the M&S/'traditional' business model trade-off can be found when analyzing the literature?.* Namely, the articles in this literature study have delivered the difference in costs and benefits of a 'traditional' (stick-built and tailor made) business model in contrast to the M&S (modular and standard) business model. Furthermore, some articles have delivered enablers and blockers that have to be taken into account.

Chapter 4. The initial 'list of conditions'

This chapter is the first analysis part of this research. In this chapter the information found in the (second) literature study (Chapter 3) will be analyzed. A ' list of conditions' will be derived from this analysis. These 'conditions' will indicate where and how the 'traditional' and M&S business model differentiate (i.e. shows the difference in costs, benefits, enablers and barriers) from each other. Furthermore, in this chapter the Business Model Canvas (BMC) theory will be applied for further comparing the two business models. This theory will also help to give the readers a more comprehensive and conceptual understanding of 'conditions' that are introduced. In general, the result of this chapter is the initial 'list of conditions' induced from the (second) literature study

Later on in this research, after the Case study chapter (Chapter 5), new elements will be added to the initial 'list of conditions' and some elements will be revised or altered on basis of the new information.

Section 4.1 The approach used for making the 'list of conditions'

The approach for the development of the 'list of conditions' is fairly simple. Namely, the literature found in the previous chapter is analyzed and the information that differentiates the 'traditional' business model with the M&S business model will be used. Furthermore, the literature that discusses the enablers and blockers of switching from the 'traditional' to M&S will also be used for analysis. This information will be classified under the so called 'conditions'. *As example, the literature might state that the cost of structural steel is higher for a plant from the M&S design due to the modular design, this will be classified under the condition 'modularity'.* Furthermore, the conditions will then be reflected with the Business Model Canvas (BMC) theory. This is useful because it puts the information in a (known) theoretical framework and might bring a more comprehensive and conceptual understanding of the information. Figure 9 gives the conceptual visualization of the approach for the development of the Initial 'list of conditions'.

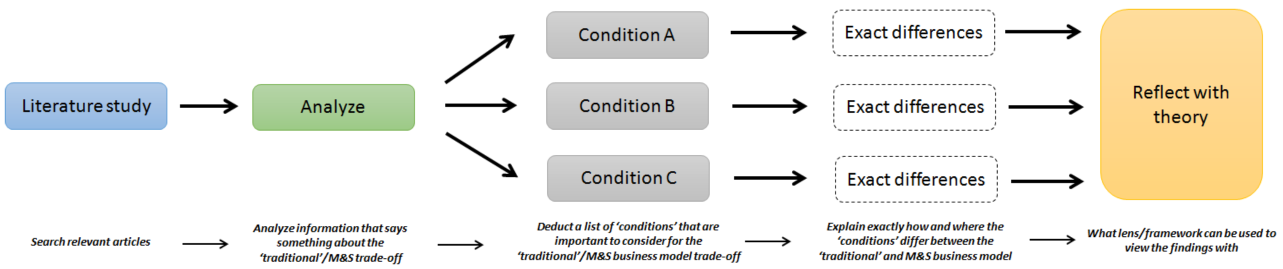

Figure 9: Conceptual visualization of the first analysis part; developing the initial 'list of conditions'

Section 4.2 Actors taken into account

The 'list of conditions' will differentiate between the 'traditional' and M&S business *model seen from the plant engineering perspective*. After all, the main goal of this research - developing the assessment questionnaire - is to assess the plant engineering trade-off ('traditional'/M&S). However, in order to ensure that this trade-off is made with the 'right' (and the appropriate information, more actors then just the plant engineer should be taken into account. Namely, the plant engineer is dependent on different actors in different situations. For example, the plant engineer is dependent upon the client to buy his product, this is thus a very important actor to take into account. Furthermore, the plant engineer is dependent upon his suppliers and subcontractors for the successful completion of the project and good functioning of his supply chain. Thus, different actors are involved in the analysis of the business models; the client, the subcontractors and the vendors. By including the perspective of more actors, a broader perspective will be taken into account, and a more informed and valid 'list of conditions' can be developed. The actors that are taken into account for this analysis are;

Clients – The client's perspective is the most important perspective to include. Namely, whether a plant engineer receives a new project is only dependent upon the client. It is thus the plant engineer's job to convince a client of the benefits of his product (i.e. a plant). For this reason, the benefits, costs, drivers and barriers for a client to choose a product from a particular business model should be perfectly understood. In order to make the decision model more reliable the client's perspective will also be included in the case study, in which the client's business case will be simulated.

Vendors – The biggest part of the cost is dependent upon the purchasing and supply of materials (about 40%). Furthermore, the schedule of a project is often dependent upon lead times from vendors. For this reason, the costs and performance of vendors play a big role in the development of projects. And how projects are developed in turn is dependent upon the business model used. It is important that the vendor and the (potential) relationship with the plant engineer are taken into account since this might save major cost.

Subcontractors - The risk profile (e.g. physical, environmental, schedule etc.) of a project is highly dependent on factors that occur during construction, in which the subcontractors play the biggest role. Furthermore, a big part of the costs (about 30%) is dependent upon the cost of subcontracting. Thus, the performance and costs of subcontractors also plays a big role in the development of projects. And how projects are developed in turn is dependent upon the business model used. It is thus important that the subcontracting view is taken into account.

Section 4.3 The initial 'list of conditions'

This section will introduce the initial 'list of conditions'. In this chapter the information from the (second) literature study (Chapter 3) is analyzed and 'conditions' are derived. The 'conditions' show on where and how the 'traditional' and M&S business model differentiate between each other. In this section the 'list of conditions' is developed with two perspectives; the plant engineering perspective and the client's perspective. After a condition is introduced the Business Model Canvas (BMC) theory is used to arrive at a more comprehensive and conceptual understanding of the material.

Conditions' from a plant engineering perspective

This section will introduce the 'conditions' that are relevant from a plant engineering perspective. At first, every conditions will be briefly introduced and explained. Next, the exact points in which the 'conditions' differentiate between the 'traditional' and M&S business model will be discussed. The 'conditions' are thus introduced in this section in the following manner; (1) briefly introducing and explain the condition and (2) analysis of how the 'condition' differentiates between the 'traditional' and M&S business model.

Condition 1: Modularity

Modularity refers to a method of plant design. A modular design means that the 'plot area', or the total layout of the plant, is split it in modules. These modules comprise of piping, vessels, heat exchangers, distillations columns or other plant materials constructed as module or 'skid'. Even though modularity is mentioned in one breath with the M&S business model, it is not mandatory to use a modular design when going standard. However, many authors (West, 2011) (O'Conner, O'Brien, & Ouk Choi, 2015) (Schulz, 2013) (Brookfield & Cooke, 2001) have written about the dynamics of a modular design in the M&S business model. By analyzing these articles the following differences were found in this condition;

(1) (O'Conner, O'Brien, & Ouk Choi, 2015) argue that standardization is much more likely to become a success when it is combined with modularization. The authors say that other engineer-to-order industries already take advantage of modularity and standardization such as the shipbuilding industry. Modularization and standardization have a synergetic action for efficiency of development and predictability of execution. (O'Conner, O'Brien, & Ouk Choi, 2015) argue that there are two ways to combine modularity with standardization; (1) develop a standard plant and split up in modules (Modularized Standard Plant) or (2) develop a modular plant and standardize some of the modules. Both ways have the same benefits and costs. Thus, modularization is an enabler, and driver, for standardization.

(2) According to (O'Conner, O'Brien, & Ouk Choi, 2015) (West, 2011) and (Schulz, 2013) a modular design entails increased cost of structural steel. They argue that since a modular design comprises several pieces of equipment and materials that are pre-assembled as a base structure that requires delicate transport measures. For this reason, it is imperative that extra effort is put into the fortification and robustness of the modules which, in turn, requires extra steel. (Schulz, 2013) Argues that there is a 20% increase in cost of structural steel for a modular design.

(3) (O'Conner, O'Brien, & Ouk Choi, 2015) and (West, 2011) discuss the transportation cost for a modular design. According to these authors the cost of transportation is always higher when applying a modular design because of two reasons. At first, they argue that in most cases a module is built on a fabrication yard which will result in two transport routes (from vendor to shop and from shop to site). Two routes requires additional coordination and more time. Secondly, the authors argue that some modules may be very large requiring special transport. This special transport can be a substantial extra cost of transport.

(4) According to (Brookfield, R; Cooke, J, 2001) and (West, 2011) another cost of a modular design are the increased coordination efforts. These authors argue that past experience shows that a modular plant requires more communication and coordination between the EPC contractor, vendors and subcontractors. This coordination and communication is required to ensure the modules will fit together as a total plant when they arrive at site. However, this is mainly a cost that occurs for the first M&S plant. Namely, for subsequent plants the standardization can ensure a more smooth coordination. Furthermore, in the case that for subsequent M&S plants the same vendors and subcontractors can be used, the coordination costs will diminish even more.

Reflecting the Business Model Canvas theory on condition 1 (plant engineering perspective)
When reflecting this condition with BMC theory (Chapter 2.4) it becomes clear that the modular approach will result in a change for Key activities in the M&S business model in relation to the 'traditional' business model. Namely, the 'traditional' plant is stick-built whilst the M&S plant is modular built. This requires major change in design and construction activities. Furthermore, there will be a change in coordination activities, since the first M&S plants will require additional coordination efforts. Another Key Activity that will change for this condition is the transport. The plant engineering should take into account that different or additional transport will be required for a modular design.

Condition 2: Procurement discounts

The condition 'Procurement discounts' is another important characteristic that can differentiate between the 'traditional' and M&S business model, it refers to discounts on materials from the supply side. (O'Conner, O'Brien, & Ouk Choi, 2015) (West, 2011) discussed the condition 'Procurement discounts' and the potential that it holds for the 'traditional' and M&S business model. Overall, when the condition 'Procurement discounts' holds it is more beneficial for the M&S business model.

(1) (O'Conner, O'Brien, & Ouk Choi, 2015) and (West, 2011) say that an enabler of the condition 'Procurement discounts' is the strength of the buyer-supplier relationship. In the case that a good buyer-supplier relationship exists between the plant engineer and a vendor the condition 'Procurement discounts' has a higher chance of holding for the M&S business model.

(2) According to (O'Conner, O'Brien, & Ouk Choi, 2015) and (West, 2011) the condition 'Procurement discounts' can has a major benefit for the M&S business model. Namely, the M&S business model requires standardized items to be ordered for every subsequent plant. This might incentivize the vendor to offer a frame agreement to the plant engineer in which he offers a lower price for materials in return for guaranteed purchases for subsequent plants. On the contrary, this is much more difficult if not impossible for the ad hoc orders from plants in a 'traditional' business model.

Reflecting the Business Model Canvas theory on condition 2 (plant engineering perspective)

When reflecting this condition with BMC theory (Chapter 2.4) it becomes clear that procurement discounts will result in change in the Key Partnerships area of the M&S business model in relation to the 'traditional' business model. Namely, when obtaining the procurement discounts the plant engineers business model will require a change in the buyer-supplier relationship.

Condition 3: Learning curve effect

The condition 'Learning curve' refers to potential to increase efficiency and productiveness on the basis of experiences and reduction of errors (e.g. through improved manufacturing processes). Many authors (Verlag, 2004) (Karim & Nekoufar, 2012) (Gepp, Vollmar, & Schaeffler, 2014) (O'Conner, O'Brien, & Ouk Choi, 2015) have discussed this topic and its relevance in the 'traditional'/M&S trade-off. The 'learning curve' effect is a condition that can be very beneficial for the M&S business model. By reviewing the literature the following differences in this condition for the 'traditional' and M&S business model were found:

(1) According to (Verlag, 2004) and (O'Conner, O'Brien, & Ouk Choi, 2015) an enabler of the 'learning curve' effect is the product volume. These authors describe the 'learning curve' effect as the cost reduction achieved on the basis of experiences, or reduction of errors (e.g. through improved manufacturing processes). The higher the degree of standardization the bigger the benefit of the learning curve is. These authors argue that the 'learning curve' effect is a function of the cumulative products produced. A high product volume is thus an enabler of the 'learning curve' effect.

(2) According to (Karim & Nekoufar, 2012) (Gepp, Vollmar, & Schaeffler, 2014) (O'Conner, O'Brien, & Ouk Choi, 2015)and (Verlag, 2004) the 'learning curve' effect can occur during the fabrication phase of a plant. The fabrication phase can be defined in two ways; (1) production of goods at the vendor (2) and/or production of modules at a fabrication shop. The articles claim that in the case that similar items are fabricated by the same vendor and/or at the same fabrication shop, experience will be built up. This increased experience ensures increased productivity and increased efficiency at this vendor which, in turn, will decrease the schedule time and the reduce schedule risk. Furthermore, this ‘learning curve’ effect can also ensure higher quality and reduced safety risk. This ‘learning curve’ effect is thus especially relevant for the M&S business model since this means that many similar items will be produced, potentially resulting in the built-up of the 'learning curve'.

(3) According to (Karim & Nekoufar, 2012) (Gepp, Vollmar, & Schaeffler, 2014) (O'Conner, O'Brien, & Ouk Choi, 2015) and (Verlag, 2004) the ‘learning curve’ effect can also occur during the construction phase. In particular, the authors claim that in case of modular construction of standard products (i.e. M&S plant) the construction phase will benefit from the ‘learning curve’ effect. In contrast, a ‘traditional’ plant will be stick-built. The materials and installation procedures are always different for a ‘traditional’ plant, thereby hampering an experience built-up. However, the M&S plant has a much smaller proportion of site-based construction and also has reduced construction complexity. When the same subcontractor is used for constructing work in the M&S business model the ‘learning curve’ effect can be enabled. This will ensure increased productivity and efficiency which will, in turn, create shorter schedules and less schedule risk for the M&S business model.

(4) (O'Conner, O'Brien, & Ouk Choi, 2015) argues that a ‘learning curve’ effect can also occur in the commissioning & start-up (CSU) of plants in the M&S business model, in case that the plant engineer is in control over this phase. During the CSU phase of a project the plant is tested and put in commission. By executing the CSU of the M&S plant a number of times the plant engineer becomes experienced and the ‘learning curve’ effect will kick in. This will ensure that the plant engineer can offer a lower price to the client and reduce the time needed for the CSU. Furthermore, since the CSU always a very critical phase of a project, the experience built-up will also result in reduced schedule risk or other contingent events which often occur in a CSU.

Reflecting the Business Model Canvas theory on condition 3 (plant engineering perspective)

When reflecting with BMC theory (Chapter 2.4) it becomes apparent that when the 'learning curve' effect increases this can result in change Key Resources in the M&S business model in relation to the 'traditional' business model. Namely, when the 'learning curve' effect grows during the commissioning & start-up (CSU) phase, the plant engineer will gain experience. This experience, in turn, will create 'tacit knowledge' (A Key Resource) of the CSU phase that would not have been the case in the 'traditional' business model.

Condition 4: Parallel manufacturing/construction

The condition ‘parallel engineering’ refers to the potential to perform engineering jobs in parallel. This is the opposite of engineering in serial, in which the start of next job is dependent upon the finishing of the previous job. (West, 2011) (O'Conner, O'Brien, & Ouk Choi, 2015) and (Meyer, 2007) have written about parallel engineering in plant engineering business or related industries. By analyzing this literature this condition could be derived because it differentiates between the 'traditional' and M&S business model. Overall, the potential to manufacture in parallel is beneficial for the M&S business model. The following can be induced about the condition ‘parallel engineering’ from the literature.

(1) According to (West, 2011) and (Meyer, 2007) an enabler of parallel engineering is a modular design. A modular design means that the plotted area of construction (i.e. all elements that make up the final plant) is subdivided in per-constructed skids/modules. In contrast, during the construction of 'traditional' stick-built design the plant is built in 'serial'. As a result some items/materials have an idle time before they can be installed (i.e. they have to wait to be constructed until another item is installed). However, unlike the 'traditional' plant the M&S plant has no idle time during construction.

(2) According to (West, 2011) (O'Conner, O'Brien, & Ouk Choi, 2015) and (Meyer, 2007) the absence of idle time directly results in time benefits. These time benefits result in a decreased schedule for building a plant in the M&S business model.

Reflecting the Business Model Canvas theory on condition 4 (plant engineering perspective)

When reflecting with BMC theory (Chapter 2.4) the potential to manufacture in parallel will not change the business model layout much regarding the M&S and 'traditional'. The only difference ce might occur in the Value Proposition. Since parallel manufacturing increased efficiency, the clients will enjoy a shorter time-to-market.

Condition 5: Using a fabrication yard

The condition 'Using a fabrication yard' refers to a controlled environment that is used to build the plant. It is a so called off-site location. In contrast, an on-site location is the location where the plant will be put in operation. Some authors (Schulz, 2013) (Haney, 2014) and (Redmon, 2006) have discussed the dynamics of using a fabrication yard in both the 'traditional' and the M&S business model. After analyzing this literature inductions were made that showed a difference exists in costs and benefits between the 'traditional' and M&S business model in this condition. The following was induced;

(1) According to (Schulz, 2013) and (West, 2011) a modular design enables the use of a fabrication yard. They argue that, since a module is a fully constructed part of plant which can be built without taking the construction of the other parts into account (i.e. of course not referring to the design), this work can be executed in a 'controlled' off-site environment (e.g. fabrication yard). In contrast, a 'traditional' plant is built part by part and all items are dependent upon each other, making it imperative to build the plant on-site (i.e. final plant site). For this reason, it is only be relevant for a modular (e.g. M&S) design to use a fabrication yard.

(2) According to (Schulz, 2013) (Redmon, 2006) (Haney, 2014) the use of a fabrication yard will mean that construction can be executed in a controlled environment (i.e. fabrication yard). As a result there will be a substantial reduction of construction hours on-site and thus more hours spent in the fabrication yard. Work in the fabrication yard is safer for numerous reasons such; it requires less work on heights, it is often a clean and neat environment and the environment is better controlled. Since the M&S business models means that plants can be built partially in a fabrication yard overall safety risk is lower for the M&S business model.

(3) (Schulz, 2013) and (West, 2011) also indicate the potential schedule risk that is common during the 'traditional' business model. Since a 'traditional' plant is always built on the on-site location in a stick-built manner this means that it is prone to bad weather conditions and sometimes difficult logistical conditions. These risks do not necessarily have to happen, however, they are so called 'schedule risks'. When using a fabrication yard these schedule risks are reduced because a fabrication yard is a controlled environment that often has a better and reachable location then the on-site location.

Reflecting the Business Model Canvas theory on condition 5 (plant engineering perspective)
When reflecting with BMC theory (Chapter 2.4) it becomes apparent the potential to use a fabrication yard for an M&S plant will result in a change in Key Activities in the M&S business model in relation to the 'traditional' business model. Namely, a fabrication yard means that the plant is built in a controlled (shop workplace) environment and not on the on-site final location. As mentioned in Condition 5, a different approach is used for construction in the fabrication shop.

Condition 6: Owning a fabrication yard

The condition ‘Owning a fabrication yard’ refers to the fact that a plant engineer owns his own fabrication yard. Some (West, 2011) refer to this as an extended degree of vertical integration. Some authors (West, 2011) (Meyer, 2007) (O'Conner, O'Brien, & Ouk Choi, 2015) have discussed the benefits and costs of vertically integrated plant engineers for both business models. This literature was analyzed and it could be induced that a difference in costs and benefits exists for this condition between the 'traditional' and M&S business model. The following was induced;

(1) (West, 2011) (O'Conner, O'Brien, & Ouk Choi, 2015) and (Meyer, 2007) argue that in case that a plant engineer has his own fabrication yard it has to the potential to store an inventory. Thus, in the case of the M&S business model this is major benefit. Namely, since a subsequent M&S plant requires the exact same materials as the previous one and inventory can be held. As a result, long lead items can be stored and lead times can thus be drastically decreased. In general, this will result in a shorter schedule for an M&S plant. Furthermore, the risk that the schedule will be overdue (i.e. schedule risk) will also be reduced when an inventory can be stored.

Reflecting the Business Model Canvas theory on condition 6 (plant engineering perspective)
When reflecting with BMC theory (Chapter 2.4) it becomes clear that when a plant engineer own his own fabrication yard this will result in change in Key Resources for the M&S business model in relation to the 'traditional' business model. Namely, owning a fabrication shop means that a the plant engineer will have a 'new' physical resource in his business model.

Condition 7: Company commitment

The condition ‘Company commitment’ is relevant for the plant engineer when switching between business models. (Villeta & Alonso, 2013) and (O'Conner, O'Brien, & Ouk Choi, 2015) have written about the importance of company commitment during a switch from ‘traditional’ operation to M&S operation. Analyzing this literature the following could be induced about the importance of company commitment when choosing between ‘traditional’ and M&S.

(1) According to (Villeta & Alonso, 2013) and (O'Conner, O'Brien, & Ouk Choi, 2015) incumbent plant engineers always have the culture to customize and optimize. These ‘cultural barriers’ are a common barrier in many organizations that face change; sometimes this is referred to as ‘Resistance to change’. Most of the employees at a plant engineering office are change averse and are unwilling to share information for fear of opposing their weakness. This ‘Resistance to change’ is a major blocker in the success of switching from the ‘traditional’ business model to M&S.

Reflecting the Business Model Canvas theory on condition 7 (plant engineering perspective)
When reflecting with BMC theory (Chapter 2.4) it becomes apparent increased company commitment will result in a change in Key resources for the M&S business model in relation to the 'traditional' business model. Namely, the involvement of upper management and the involvement of the right 'spokesman' to change the mindset of the company requires additional resources.

Definitely during the beginning of implementing the M&S business model this should be seen as an additional resource of the M&S business model.

Conditions' from a clients perspective

This section will introduce the 'conditions' that are relevant from a clients perspective. Logically, the client will have totally different conditions which are of relevance for his decision to choose a certain type of plant. Some conditions that were highlighted in the previous section (e.g. reducing schedule) also affect the client in one way or another (i.e. client also benefits from shorter schedules). This sections will thus introduce the conditions of relevance from a clients perspective by using the (second) literature study (Chapter 3). The conditions will be introduced as following; (1) briefly introducing and explain the condition and (2) analysis of how the 'condition' differentiates between the 'traditional' and M&S business model.

Condition 1: Investment costs

The condition 'Investment costs' refers to the required capital expenditure by the client for purchasing his production plant. Some authors (Amberg, Gepp, & Horn, 2012) (Haney, 2014) (O'Conner, O'Brien, & Ouk Choi, 2015) (Verlag, 2004) have discussed the effect of an M&S or 'traditional' plant on the investment costs. According to the above-mentioned authors the plants produced in the M&S business model will eventually require less capital expenditure than plants from the 'traditional' business model. This is due to a number of reasons found in the literature and discussed below;

(1) According to (O'Conner, O'Brien, & Ouk Choi, 2015) (West, 2011) the M&S business model has the potential to benefit from procurement discounts (see condition Procurement discounts). These discounts can, in turn, lower the price for a plant offered to clients. As a result, the investment costs will go down for the client.

(2) According to (Verlag, 2004) (Karim & Nekoufar, 2012) (Gepp, Vollmar, & Schaeffler, 2014) (O'Conner, O'Brien, & Ouk Choi, 2015) the 'learning curve' effect can increase productivity in the long haul. Higher productivity can also lead to lower unit costs of vendors and subcontractors. Thus, for subsequent M&S plants cost savings from this increased productivity might be passed on in a lower price and thus reduced investment costs for the client.

(3) According to (Haney, 2014) and (Villeta & Alonso, 2013) the M&S business model allows the plant engineer to offer operator training programs. Namely, since the M&S plant is similar for every client, the plant engineer can create a 'best practice' training program. Such a training program offers a more affordable solution for the client than when training operators for tailor made 'traditional' plants.

Reflecting the Business Model Canvas theory on condition 1 (Clients perspective)

When reflecting with BMC theory (Chapter 2.4) it becomes clear that the lower investment costs brings forth a change in Value Proposition for the M&S business model in relation to the 'traditional' business model. Namely, the price offering of the M&S business model is more attractive to clients in relation to the price offering from the 'traditional' plant.

Condition 2: Schedule

The condition 'Schedule' refers to the time need for a plant to go from in development to in operation. Many authors (Verlag, 2004) (Karim & Nekoufar, 2012) (Gepp, Vollmar, & Schaeffler, 2014) (O'Conner, O'Brien, & Ouk Choi, 2015) (Schulz, 2013) and (Villeta & Alonso, 2013) have discussed the effect of the modularization and standardization on the schedule time in comparison to a 'traditional' plant. In general, an M&S plant has a shorter schedule then a similar 'traditional' plant due to the following reasons;

(1) According to (Verlag, 2004) (Karim & Nekoufar, 2012) (Gepp, Vollmar, & Schaeffler, 2014) and (O'Conner, O'Brien, & Ouk Choi, 2015) the 'learning curve' effect occurs during many phases in an EPC project. And as explained in the condition 'Learning curve' effect, this effect can entail a substantial increase in working efficiency for plants from the M&S business model. An increased efficiency simply means that more work can be done in a shorter time. As a result, the schedule for a client will be reduced with an M&S plant.

(2) According to (West, 2011) (O'Conner, O'Brien, & Ouk Choi, 2015) and (Meyer, 2007) the condition 'Parallel manufacturing' will result in decreased time required for the construction of and M&S plant. This will directly result in a shorter schedule for an M&S plant.

Reflecting the Business Model Canvas theory on condition 2 (Clients perspective)
When reflecting with BMC theory (Chapter 2.4) it becomes apparent that a shorter time-to-market, or shorter schedule, means that there is difference in Value Proposition for the M&S business model in relation to the 'traditional' business model. Namely, plants in the M&S business model will have an improvement in delivery time in relation to plants from the 'traditional' business model.

Condition 3: Risk

The condition 'Risk' can entail many types of risk. The authors to (Schulz, 2013) (Haney, 2014) (Redmon, 2006) and (O'Conner, O'Brien, & Ouk Choi, 2015) have discussed some of the risks that can be expected for 'traditional' plants and with an M&S plant. Analyzing this literature some differences were found in risk between both business models. The following could be induced from the analysis of the literature;

(1) According to (Schulz, 2013) (Haney, 2014) and (Redmon, 2006) the development of a plant in a fabrication yard lowers the risk of delays in the schedule. The authors argue that the use of a fabrication yard excludes the potential of delays due to bad weather conditions or other exogenous environmental conditions. Furthermore, they argue that a fabrication yard gives a more potential to work 24/7. In general the authors argue that the controlled environment of the fabrication shop reduces potential schedule overruns. This reduction in schedule risk is a beneficial point for the plant engineer but also for the client.

(2) (O'Conner, O'Brien, & Ouk Choi, 2015) claim that the operational risk can be reduced for clients whom operate an M&S plant. The authors argue that the first year of operation for 'traditional' plants is always critical and many contingent events can happen during this period. Due to the standardized nature of the M&S plants a 'best practice' for the initial operation phase can be used. This would reduce the operational risk which is an important benefit of the M&S business model.

Reflecting the Business Model Canvas theory on condition 3 (Clients perspective)
When reflecting with BMC theory (Chapter 2.4) it becomes clear that the reduction in risk brings forth a change in Value proposition for the M&S business model in relation to the 'traditional' business model. Namely, the M&S business model will offer less risk then the 'traditional' business model.

Chapter 5. The case study and interviews

The second data source is the Case study. The methods of data collection for this case study are; (1) The in depth case study and the (2) Client cost simulation and (3) the expert interviews. This chapter will introduce the Case study in general, the company and specifics of the case study and the details of the individual data collection methods. In short, the case study is performed at Technip, an incumbent plant engineer. The author will look into their Hydrogen technology line. Furthermore, the data collection methods that will be discussed in this chapter are;

1. In depth case study
2. Cost simulation for client
3. Interview's

The *In depth case study* consists of a financial simulation that is developed in association with Technip Benelux and has resulted in information that 'views' the situation from the plant engineering perspective. The *Cost simulation for the client* will be a financial simulation that is developed in association with Technip Benelux and has resulted in information that 'views' the situation from the clients perspective. The interviews have resulted in qualitative information from experts from the plant engineering industry. The data from these three sources will be further analyzed in Chapter 6 (Reflected 'list of conditions').

Section 5.1 Introducing the case company; Technip Zoetermeer

The case company is Technip Zoetermeer a subsidiary of Technip S.A.. Technip S.A. is one of the world's largest incumbent EPC contractors active in the on-shore, off-shore and subsea business. Technip Zoetermeer (Technip) is specialized in Hydrogen and Ethylene on-shore EPC projects, which they built as per client specification in a 'stick-built' manner. Since the academic research problem (Chapter 1) referred to incumbent on-shore plant engineers that operate the 'traditional' business model, Technip has a good fit.

Section 5.2 Introduction to in depth case study

The role of the in depth case study in this thesis is to obtain data for the Reflected 'list of conditions' (Chapter 6). This Reflected 'list of conditions' will then be used to develop a *assessment questionnaire*. This in depth case study was developed in close coordination with professional cost estimators from Technip. For this in depth case study certain assumptions were made about the scenario for the introduction of M&S. This section will introduce the scenario that has been taken into account for this in depth case study. Furthermore, this section will explain the set-up of the in depth case study.

The scenario

The scenario used for this in depth case study is based on the current situation for Technip. This situation is as follows; Currently, the plant engineer produces plants only in a 'traditional' manner. *To make the trade-off more obvious* the plant engineer wishes to compare a radical change from 'traditional' to M&S (i.e. its either 'traditional' or M&S). There are thus two options; (1) stay 'traditional' or go M&S. The scenario of the in depth case study is based purely on a *cost comparison* between the cost of developing and selling a plant.

The scenario assumes that M&S is a novel strategy for the plant engineer. In other words, there is no previous experience with standardization of 'entire' plants or modularization. Furthermore, no modules from previous plants can be used for the M&S plant, everything has to be designed from scratch. The scenario does not take any intra-company barriers into account. In other words, the company culture is deemed positive and the cost of managing change is assumed to be zero. For the sake of simplification this scenario assumes that the costs of a 'typical traditional plant' - with the same scope and technology of course - are similar in price. Furthermore - as you will also see explained further in the in depth case study - the cost of the first M&S plant are assumed to be higher. The subsequent, or nth, M&S plants are assumed to be substantially lower. Figure 10 gives a visual representation of the scenario for the in depth case study.

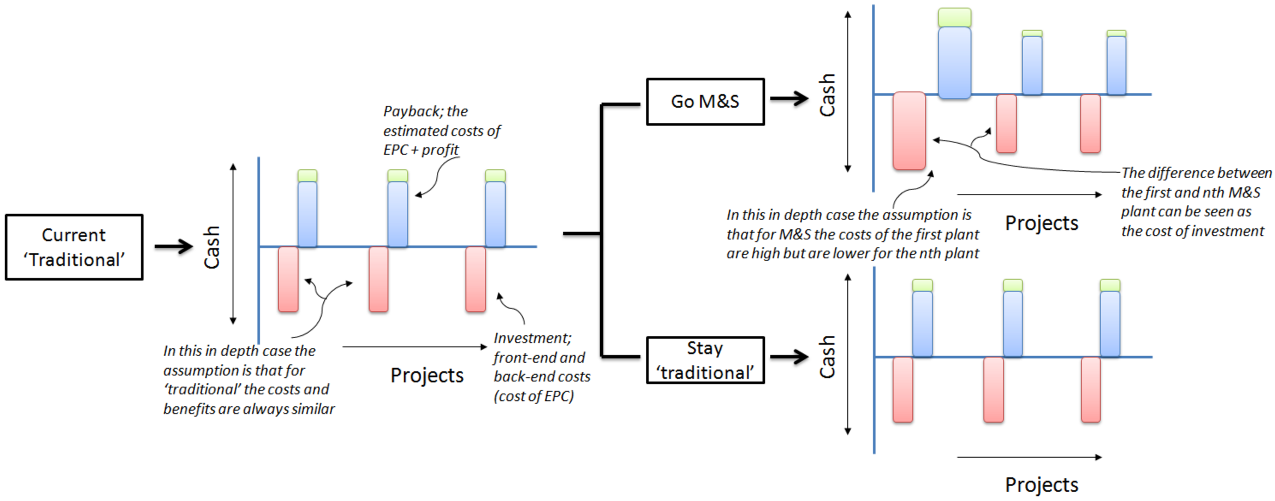

Figure 10: Visual representation of the scenario for the in depth case study

The structure and set-up

To be able to deliver the appropriate data, the in depth case study was designed in such a manner so that it allows a comparison between the 'traditional' business model and M&S business model. The scenario explained the vision of the in depth case study and mentioned a few assumption that were taken into account. The structure will be based on easily quantifiable data (i.e. costs and revenues of plants). This easily quantifiable data are cost estimates of the plants from the different business models. Three cost estimates were developed; the first is a *'typical traditional plant'* the second is the *first M&S plant* and the third is the *nth M&S plant*. The *'typical traditional plant'* will be compared with the *first M&S plant* and the *'typical traditional plant'* will be compared with the *nth M&S plant*. The financial comparison is partially backed up by arguments from the Technip cost estimators explaining why some of the financial differences occur. Figure 11 gives a visual representation of the in depth case study structure and set-up. The *'typical traditional plant'* is also referred to as the nth 'traditional' plant.

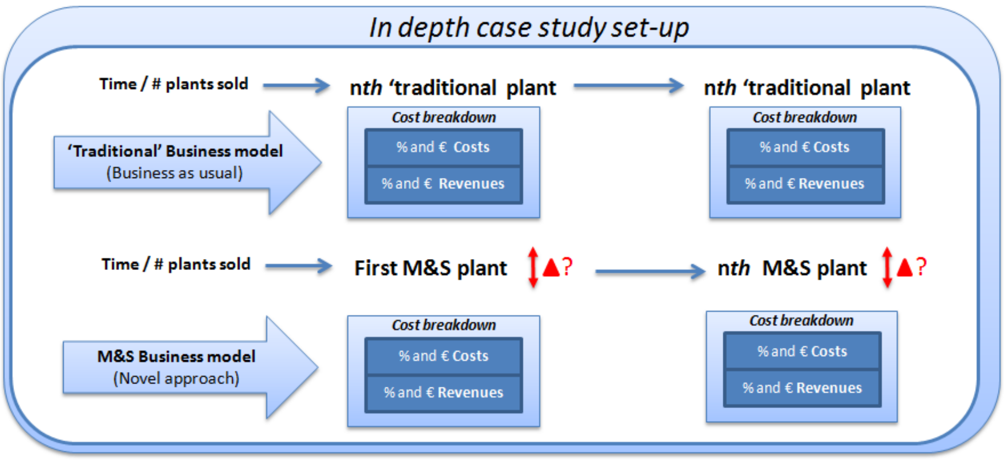

Figure 11: Approach of the in depth case study

The case of Hydrogen plants

The in depth case study will use cost estimates from the Hydrogen business line. This is due to the fact that Technip is also considering the 'traditional'/M&S trade-off for their own (Hydrogen) business. In their case they are considering the trade-off for medium to small scale hydrogen plants on an EPC basis. Currently, Technip delivers their Hydrogen plants to clients that own large oil refineries which use hydrogen as utility for other process on the refinery. Exactly, how generelizable this business line is will be discussed in a later stage in this thesis. The details and scope of the plant in the case study are given below.

Type:	Hydrogen plant (Steam Reforming Technology)
Capacity:	15.000 Nm3/h
Location plant:	Europe, Rotterdam
Location fabrication shop:	Europe, Rotterdam
Contract scope:	EPC
Concept 'traditional' plant:	Customized design & stick-built development
Concept 'M&S' plant:	Standardized design & modular development

Section 5.3 The in depth case study

This section has three purposes; (1) it will introduce the estimates for the *first M&S* and *nth M&S* plant and (2) it will introduce estimates a 'traditional' plant and (3) it will explain what information can be drawn from this in depth case study. The information from this in depth case study will be used to derive the Reflected 'list of conditions' that differentiates the 'traditional' business model from the M&S business model. Table 2 gives a summary of the data from the financial case study.

Table 2: High level summary of in depth case study

Financial structure of a plant	Traditional cost	% of total cost	first M&S cost	% of total cost	Δ	nth M&S cost	% of total cost	Δ
Home office	[redacted]	21	[redacted]	21	0	[redacted]	7	-3020
Vendor (supply)	[redacted]	39	[redacted]	50	2535	[redacted]	61	2535
Subcontracting (construction)	[redacted]	25	[redacted]	14	-2209	[redacted]	17	-2209
Total 'cost of EPC'	[redacted]	85	[redacted]	**85**	**326**	[redacted]	**85**	**-2694**
Factors	[redacted]	15	[redacted]	15	55	[redacted]	15	-478
Selling price	[redacted]	100	[redacted]	**100**	**381**	[redacted]	**100**	**-3172**

Cost structure of plants

The completion of the EPC phase for chemical projects all require 'typical' activities per project phase. These activities require financial resources burdened by the plant engineer. For this reason, the plant engineer inquires all the costs of those activities in its cost structure, known as the price sheet, so that he can me accurate estimates for every cost. Basically, the plant engineer estimates the *cost of EPC* and then adds a profit on top of the cost which in total makes the *selling price* of the plant (see figure 12).

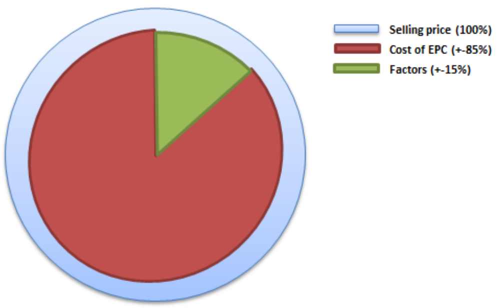

Figure 12: Abstract representation of the cost structure of plant projects

As seen in figure 12, the cost structure consists of two major elements; the ‘cost of EPC’ and the ‘factors’. The ‘cost of EPC’ refers to the costs of a project from initial estimate to start-up. The ‘Cost of EPC’ can be subdivided in three elements; (1) the home office, (2) the vendor cost and (3) the subcontracting cost. The ‘factors’ are a percentage of the selling price and represent the costs to cover certain overheads, bank guarantees, insurances, royalties and the profit of the plant engineer.

- Home office cost – These are the costs that arise from the internal work at the plants engineers home office. Generally consisting of the (discipline) engineering function that develop the plant, the procurement and subcontracting specialists that negotiate and liaison with vendors and subcontractors, the managers that control and mitigate the projects etc.
- Vendor cost – These are the costs for the supply of materials. When the plant engineer has designed his plant for a client, the materials will be bought at several vendors. These transactions between the plant engineer and vendor, including the compliance costs (expediting) and logistics (shipping), are the costs accrued to the ‘vendor cost’.
- Subcontracting cost – The cost of assembly and installation of the material that will make up the final plant. Just like the ‘vendor cost’, multiple subcontracting parties are mostly involved.
- Factors – The factors are prices added as a percentage of the selling price that make up major overhead items such as; royalties, insurances, bank guarantees and the profit.

Introducing the details of the in depth case study

This section will discuss the in depth case study in more detail. From this section it should become clear what relevant information can be used for developing the Reflected 'list of conditions' (Chapter 6). The structure of this section is as follows; (1) the cost elements of a plant will be introduced and explained in detail (2) the results will be introduced and (3) there is explained what information is useful for analysis in Chapter 6 (Reflected 'list of conditions').

Detailed home office cost breakdown

The home office costs are those costs incurred during the actual engineering of the plant. These costs thus arise mostly during the engineering phase of an EPC project. In more specific, the home office costs arise from the hours spent by personnel at the plant engineering home office. These personnel costs can be generally subdivided in the discipline engineering functions, the procurement functions, the construction functions, the support and planning functions and the project management functions. The details of the home office costs from the in depth case study can be found in table 3. Now follows a more detailed explanation of the functions from which costs are incurred during projects:

- Discipline engineering functions – These are the functions that are directly involved in the actual design of the plant. Plant design starts with the process engineering function which lays the foundation (‘Basis of Design’) for the plant, from this point onward the other plant requirements (e.g. mechanical, electrical, rotating, instruments etc.) are added to make a fully engineered plant.
- Procurement functions – This function is responsible for the supply of materials and the logistics during an EPC project. The project buyers procure the materials required for the plant from the vendors as soon as the appropriate information from the discipline engineers is available. Then, the expediters & shippers ensure a smooth functioning of the supply chain and the quality controllers guarantee the quality of the supplied materials.

- **Construction functions** – This function is responsible for the assembly, construction and installation of all plant materials into the final plant. The construction specialists ensure the proper subcontractors are hired for the project by negotiating and liaising sessions.
- **Support and planning functions** – This is a summarizing term that encompasses all the functions required to ensure an EPC project is possible at the plant engineer. Typical support functions are the financial functions (e.g. project controls and accounting), document and authority approval functions and cost estimating.
- **Project management functions** – This function entails the project management of an EPC project.

Table 3: Detailed outlay of home office cost from in depth case study

	# hours required (hr) *Δ measured in relation to Traditional*					Costs incurred (€) *Δ measured in relation to Traditional*				
Home office costs	**Traditional**	**First M&S**	**% Δ**	**Nth M&S**	**% Δ**	**Traditional**	**First M&S**	**% Δ**	**Nth M&S**	**% Δ**
Project management	[redacted]	[redacted]	0	[redacted]	-62.44	[redacted]	[redacted]	0	[redacted]	-62.4
Purchasing	[redacted]	[redacted]	0	[redacted]	-50.00	[redacted]	[redacted]	0	[redacted]	-50.0
Expediting & Shipping	[redacted]	[redacted]	0	[redacted]	-49.98	[redacted]	[redacted]	0	[redacted]	-50.0
Quality control	[redacted]	[redacted]	0	[redacted]	-10.01	[redacted]	[redacted]	0	[redacted]	-10.0
Instrumentation & Electrical	[redacted]	[redacted]	0	[redacted]	-90.00	[redacted]	[redacted]	0	[redacted]	-90.0
Rotating equipment	[redacted]	[redacted]	0	[redacted]	-	[redacted]	[redacted]	0	[redacted]	-
Civil engineering & static equipment	[redacted]	[redacted]	0	[redacted]	-90.00	[redacted]	[redacted]	0	[redacted]	-90.0
Piping	[redacted]	[redacted]	0	[redacted]	-91.16	[redacted]	[redacted]	0	[redacted]	-91.2
Furnace internals and steel	[redacted]	[redacted]	0	[redacted]	-90.00	[redacted]	[redacted]	0	[redacted]	-90.0
Document & authority approval	[redacted]	[redacted]	0	[redacted]	0.00	[redacted]	[redacted]	0	[redacted]	0.0
Construction home office	[redacted]	[redacted]	0	[redacted]	-89.99	[redacted]	[redacted]	0	[redacted]	-90.0
Process engineering	[redacted]	[redacted]	0	[redacted]	-90.00	[redacted]	[redacted]	0	[redacted]	-90.0
Commissioning home office	[redacted]	[redacted]	0	[redacted]	0.00	[redacted]	[redacted]	0	[redacted]	0.0
Sales & Business development	[redacted]	[redacted]	0	[redacted]	0.00	[redacted]	[redacted]	0	[redacted]	0.0
Estimating & planning	[redacted]	[redacted]	0	[redacted]	-4.39	[redacted]	[redacted]	0	[redacted]	-4.4
Cost control & accounting	[redacted]	[redacted]	0	[redacted]	0.00	[redacted]	[redacted]	0	[redacted]	0.0
Unallocated costs	[redacted]	[redacted]	0	[redacted]	-	[redacted]	[redacted]	0	[redacted]	-
Technical contingencies	[redacted]	[redacted]	-	[redacted]	-	[redacted]	[redacted]	-	[redacted]	-
GRAND TOTAL Home office	[redacted]	[redacted]	0	[redacted]	-36370	[redacted]	[redacted]	0	[redacted]	-3020

As can be seen from table 3 the home office costs were obtained by summarizing the hours per spent per function - on basis of the case project - and then multiplying this with the associated hourly rate. The hours per project are estimated by the particular function themselves on the basis of their previous experience. For the in depth case study the hours were obtained by professional cost estimators from Technip on basis of their reference projects. In this case study an average hourly rate of €80 is assumed for every function.

Detailed vendor cost breakdown

The vendor costs are those costs incurred by the purchasing and supply of materials require for the plant. These costs are spread out over the procurement phase of a project. Materials that require a long delivery time (i.e. long lead materials) will be purchased early in the procurement phase, materials with shorter delivery times can be purchased later. Vendor costs', and thus the supply of materials, are typically subdivided into three elements; major equipment, bulk materials and others' equipment. Below is a more detailed explanation of the vendor costs.

- **Major equipment** – These are often the materials that have the longest lead times. The 'major equipment' items are also often very specific to a certain type of process. For the plant from the in depth case study the 'major equipment' item is the steam reformer, in which the hydrogen is actually produced through a reaction with water (steam).
- **Bulk materials** – As the word says the bulk materials are relatively abundant items. Bulk materials are valves, piping lines, electrical wiring, structural steel etc. Bulk materials are required for every plant and often have relatively short lead times.

- **Others' equipment** – The 'others' equipment' lie in between major equipment and bulk materials. Namely, they are not as abundant as the bulk materials but they are often required in most other processes. Typical 'Others' equipment' are vessels, heat exchangers, filters etc. The lead time lies in between that of major equipment and bulk materials.
- **Miscellaneous vendor** – In this case Miscellaneous vendor costs are the costs of transportation and the technical contingencies. Technical contingencies are calculated in the cost estimate to cover the potential risks, in this case late delivery and material damage.

Table 4: Detailed outlay of vendor cost from in depth case study

Vendor costs	Costs incurred (€) *Δ measured in relation to Traditional*				
Reformer supply	**Traditional**	**First M&S**	**% Δ**	**Nth M&S**	**% Δ**
Steel	[redacted]	[redacted]	332.7	[redacted]	332.7
Refractory	[redacted]	[redacted]	0.0	[redacted]	0.0
Reformer tubes	[redacted]	[redacted]	20.7	[redacted]	20.7
Convection	[redacted]	[redacted]	0.0	[redacted]	0.0
Burners	[redacted]	[redacted]	135.2	[redacted]	135.2
Fans	[redacted]	[redacted]	0.0	[redacted]	0.0
Boilers	[redacted]	[redacted]	0.0	[redacted]	0.0
Others	[redacted]	[redacted]	0.0	[redacted]	0.0
Total reformer	[redacted]	[redacted]	**96.4**	[redacted]	**96.4**
Bulk material supply	[redacted]	[redacted]	**% Δ**	[redacted]	**% Δ**
Piping	[redacted]	[redacted]	1.4	[redacted]	1.4
Instrumentation	[redacted]	[redacted]	0.0	[redacted]	0.0
Electrical	[redacted]	[redacted]	0.0	[redacted]	0.0
Plant steel	[redacted]	[redacted]	-60.5	[redacted]	-60.5
Total Bulk	[redacted]	[redacted]	**-2.9**	[redacted]	**-2.9**
Other plant equipment supply	[redacted]	[redacted]	**% Δ**	[redacted]	**% Δ**
Reactors & Internals	[redacted]	[redacted]	0.0	[redacted]	0.0
Heat exchangers	[redacted]	[redacted]	0.0	[redacted]	0.0
Drums & other vessels	[redacted]	[redacted]	0.0	[redacted]	0.0
Catalysts & Chemicals	[redacted]	[redacted]	0.0	[redacted]	0.0
PSA	[redacted]	[redacted]	0.0	[redacted]	0.0
Total plant equipment	[redacted]	[redacted]	**0.0**	[redacted]	**0.0**
Grand Total material supply	[redacted]	[redacted]	**32.0**	[redacted]	**32.0**
Miscellaneous vendor	[redacted]	[redacted]	**% Δ**	[redacted]	**% Δ**
Transportation (5% of total material supply)	[redacted]	[redacted]	32.2	[redacted]	32.2
Technical contignencies (7% of total mat sup	[redacted]	[redacted]	37.3	[redacted]	37.3
Total miscellaneous vendor	[redacted]	[redacted]	**35.1**	[redacted]	**35.1**
GRAND TOTAL vendor	[redacted]	[redacted]	**32.4**	[redacted]	**32.4**

The 'traditional' costs found in table 4 were obtained via reference plants. The costs for the M&S plants were obtained by expert estimation relative to the 'traditional' plants. However, in case of a detailed estimate is required (e.g. for new proposals/tenders etc.) the vendor costs are obtained by quotes from the vendors. When an item is a true 'repeat order' by nature (e.g. certain bulk materials) prices can be obtained by checking price lists.

Detailed subcontracting cost breakdown

The subcontracting costs are those costs incurred due to the assembly and installation of the materials which make up to be the final plant. The costs are borne by the plant engineer but are, in the case for Technip, outsourced to subcontracting parties. Most of the subcontracting costs occur during the construction phase of a project. However, some subcontracting work (e.g. civil works) can already start during the procurement phase. The subcontracting costs have the same subdivision as the vendor costs (i.e. major equipment, bulk materials and others' equipment), for this reason, the items will not be explained again. The only different cost items are 'Miscellaneous construction' which involves supervision costs and technical contingencies.

Table 5: Detailed outlay of subcontracting cost from in depth case study

Construction costs	Standard Man-hours required (hr) *Δ measured in relation to Traditional*					Costs incurred (€) *Δ measured in relation to Traditional*				
Reformer installation	**Traditional**	**First M&S**	**% Δ**	**Nth M&S**	**% Δ**	**Traditional**	**First M&S**	**% Δ**	**Nth M&S**	**% Δ**
Steel	[redacted]	[redacted]	52.7	[redacted]	52.698159	[redacted]	[redacted]	52.7	[redacted]	1257.2
Refractory	[redacted]	[redacted]	-90.0	[redacted]	-90.001733	[redacted]	[redacted]	-90.0	[redacted]	-148.1
Reformer tubes	[redacted]	[redacted]	-26.7	[redacted]	-26.739927	[redacted]	[redacted]	-26.7	[redacted]	-156.1
Convection	[redacted]	[redacted]	-71.7	[redacted]	-71.723122	[redacted]	[redacted]	-71.7	[redacted]	-140.2
Burners	[redacted]	[redacted]	185.7	[redacted]	185.71429	[redacted]	[redacted]	185.7	[redacted]	-80.6
Fans	[redacted]	[redacted]	-10.0	[redacted]	-10	[redacted]	[redacted]	-10.0	[redacted]	-133.8
Boilers	[redacted]	[redacted]	0.0	[redacted]	0	[redacted]	[redacted]	0.0	[redacted]	#DIV/0!
Others	[redacted]	[redacted]	-25.0	[redacted]	-25	[redacted]	[redacted]	-92.5	[redacted]	-101.2
Total reformer	[redacted]	[redacted]	**-18.6**	[redacted]	**-18.615114**	[redacted]	[redacted]	**-18.6**	[redacted]	**-18.6**
Bulk material installation	[redacted]	[redacted]	**% Δ**	[redacted]	**% Δ**	[redacted]	[redacted]	**% Δ**	[redacted]	**% Δ**
Piping	[redacted]	[redacted]	-64.1	[redacted]	-64.107101	[redacted]	[redacted]	-64.1	[redacted]	-812.0
Instrumentation	[redacted]	[redacted]	61.3	[redacted]	61.290323	[redacted]	[redacted]	61.3	[redacted]	878.9
Electrical	[redacted]	[redacted]	-100.0	[redacted]	-100	[redacted]	[redacted]	-100.0	[redacted]	-100.0
Plant steel	[redacted]	[redacted]	-100.0	[redacted]	-100	[redacted]	[redacted]	-100.0	[redacted]	-100.0
Insulation	[redacted]	[redacted]	-72.7	[redacted]	-72.734457	[redacted]	[redacted]	-72.7	[redacted]	-206.7
Total Bulk	[redacted]	[redacted]	**-57.3**	[redacted]	**-57.272034**	[redacted]	[redacted]	**-57.3**	[redacted]	**-57.3**
Others equipment installation	[redacted]	[redacted]	**% Δ**	[redacted]	**% Δ**	[redacted]	[redacted]	**% Δ**	[redacted]	**% Δ**
Reactors & Internals	[redacted]	[redacted]	66.1	[redacted]	66.081871	[redacted]	[redacted]	66.1	[redacted]	-67.8
Heat exchangers	[redacted]	[redacted]	252.1	[redacted]	252.06612	[redacted]	[redacted]	252.1	[redacted]	-87.3
Drums & other vessels	[redacted]	[redacted]	373.3	[redacted]	373.33333	[redacted]	[redacted]	373.3	[redacted]	-97.1
Catalysts & Chemicals	[redacted]	[redacted]	0.0	[redacted]	0	[redacted]	[redacted]	0.0	[redacted]	#DIV/0!
PSA	[redacted]	[redacted]	-100.0	[redacted]	-100	[redacted]	[redacted]	-100.0	[redacted]	-100.0
Heavy lifts	[redacted]	[redacted]	-	[redacted]	-	[redacted]	[redacted]	-	[redacted]	-
Total Others equipment	[redacted]	[redacted]	**-35.1**	[redacted]	**-35.096909**	[redacted]	[redacted]	**34.7**	[redacted]	**34.7**
Grand Total installation	[redacted]	[redacted]	**-47.1**	[redacted]	**-47.062**	[redacted]	[redacted]	**-43.2**	[redacted]	**-43.2**
Miscellaneous construction	[redacted]	[redacted]	*% Δ*	[redacted]	*% Δ*	[redacted]	[redacted]	*% Δ*	[redacted]	*% Δ*
Expetriate supervision	[redacted]	[redacted]	-	[redacted]	-	[redacted]	[redacted]	-	[redacted]	-
Local supervision	[redacted]	[redacted]	-	[redacted]	-	[redacted]	[redacted]	-	[redacted]	-
Technical contignencies	[redacted]	[redacted]	-	[redacted]	-	[redacted]	[redacted]	-	[redacted]	-
Total miscellaneous construction	[redacted]	[redacted]	-	[redacted]	-	[redacted]	[redacted]	-	[redacted]	-
GRAND TOTAL Constructio	[redacted]	[redacted]	***-47.1***	[redacted]	***-47.06248***	[redacted]	[redacted]	**-43.2**	[redacted]	**-43.2**

The costs of subcontracting (table 5) are determined by research what the 'standard man-hours required' are to complete the installation and construction. These 'standard man-hours required' are then multiplied with the 'hourly rate' of the particular location of construction. The 'hourly rate' differs for every location. Furthermore, the labor on every location has a different 'productivity rate'. Thus, the 'standard man-hours required' are also multiplied with the 'productivity rate' of the location of construction. For this in depth case study the location The Netherlands (Rotterdam) Rotterdam was assumed fir building the plant. Thus, for the 'traditional' business model this means the plant is constructed in Rotterdam and for the M&S business model this means that the fabrication yard as well as the final plant site is Rotterdam. The 'standard man-hours required' for this case were obtained by reviewing past reference plants. The 'hourly rate' in Rotterdam was assumed to be €80 and the 'productivity rate' is 1. In case of a detailed estimates (e.g. for new proposals/tenders etc.) the subcontracting rates are obtained by quotes from the subcontractors in negotiation with the construction experts from the plant engineer.

Section 5.4 Introduction to the client cost simulation

During preliminary information gathering, and as mentioned in the Chapter 1 (Background and introduction), there is a major trade-off between plant capacity and efficiency. Preliminary information gathering showed that standardization only becomes relevant for the client for *lower plant capacities*. Namely, it is argued that the share of the OPEX of the plant becomes more important in relation to the CAPEX the larger the plant capacity is. Furthermore, it is argued that an M&S plant is less efficient then a 'traditional' plant. This results in a relation between the OPEX, CAPEX and the plant capacity for the 'traditional' and M&S business model. This relationship will be tested with the 'Client cost simulation'. The 'Client cost simulation' will simulate the effect of plant capacity on OPEX and CAPEX, taking into account the speculated 'lower' efficiency of an M&S plant.

The approach for this client cost simulation will take the shape of a cash flow analysis that includes some capital budgeting techniques (e.g. NPV analysis). A 'scenario' will be developed that simulates the above-mentioned relationship. The purpose of this client cost simulation will be to gather information that helps to differentiate between the 'traditional' and M&S business model. This chapter will only introduce the cost simulation and the results, the results will be further analyzed and discussed in the next chapter (Chapter 6).

Designing the client cost simulation

The client cost simulation was set-up with close coordination of Technip’s cost estimating experts. The design of the client cost simulation consists of the framework used for the simulation, the assumptions made in the simulation and the data collection for the simulation. The client cost simulation will be in the form of a cash flow simulation for the client.

The framework of the client cost simulation

For the framework of the client cost simulation is partially adopted from a tool used by plant engineering cost estimators; The Aspen In-plant Capital and Maintenance projects program, and partially from the article of (Schmidt, 2003). The most important elements from the framework of the client cost simulation are explained below.

- **Capital expenditure (CAPEX)** – The CAPEX is the investment costs in the plant for the client. It represents the cost of the product (i.e. the plant) developed by the plant engineer consisting of the ‘Cost of EPC’ and the ‘Factors’ as mentioned in section 5.3 during the in depth case study.
- **Operational expenditure (OPEX)** – The OPEX are the costs required ‘to keep the plant running’. A client calculates the raw materials, utilities, operational staff and maintenance as costs required to do daily business.
- **Product revenue** – This is the only source of income for a manufacturing plant; it is the selling price of his product times the product sold. By taking into account the life cycle of the plant – that is the number of years is at least expects the plant to produce product – the product revenue should be bigger than all the costs.
- **Overheads** – The overheads are ongoing expenses regardless of whether a company is doing a high or low volume of business.
- **Depreciation** – Depreciation is an input that is added in companies’ income statements for accounting purposes. It indicates how much of an assets value has been used up.
- **Earnings Before Interest and Taxes (EBIT)** – The EBIT are the company’s bottom line before it is exposed to taxes. Since the assumption for the simulation is that taxes are not taken into account this is the bottom line in the business case.
- **Net Present Value (NPV)** – The NPV rule is the most important capital budgeting rule. This rule is used to calculate the present worth of cash by using a formula in which a discount rate is used that represent the ‘rate of return’ that could be earned on a different investment with similar risk
- **Period of operation** – The period of operation is an important parameter for the client since it tells how much profit it can make on basis of a lifecycle estimation taking into account the all the costs and revenues.

Data collection for the cost simulation

Critical for the validity of the client cost simulation are the methods and sources used for the collection of the data. Data was collected from an estimate that was simulated with the Aspen In-plant Capital and Maintenance projects program together with a professional cost estimator. As mentioned before, this program is used by Technip to set-up basic business cases for the client (for plants from the 'traditional' business model). The collected data from the simulation represents the client's business case for a relatively large 160.000Nm3/h hydrogen plant (thus including the development of OPEX and revenue in a number or years). This data will be reflected with information we have on the M&S business model to understand how the client's business case will change for a plant from the M&S business model. This manipulation is accomplished by using information from the in-depth case study and by manually changing variables to see how the data is affected (see section 5.3). Below is further explained how the data is collected;

Capital Expenditure (CAPEX) – The CAPEX for the client's business case are the 'Cost of EPC' for the plant engineer. The simulation from the Aspen In-plant Capital and Maintenance projects program showed that for a plant of 160.000 Nm3/h the CAPEX were €130.000.
Operational expenditure (OPEX) – As mentioned in the previous section the OPEX consists of numerous elements. This simulation distinguishes between the fixed OPEX (e.g. labor, maintenance, supervision etc.) and the variable OPEX (e.g. raw materials and utilities). For the plant of 160.000 Nm3/h the following OPEX were found; Average feed cost per month are €1.160.000, Average utility cost per month are €5.380.000, Average labor cost per month are €4.510.000, Average maintenance cost per month are €1.160.000, Average overheads per month are €2.840.000. The OPEX associated with plants with the different capacities were found by using the appropriate dividing factor based on the proportions of 160.000 Nm3/h plant.
Product revenue – The price of a product is the only source of income for a plant. Since some markets can be very volatile it is very difficult to make an assessment of the cost hydrogen. Technip utilizes his own database to estimate the market price of industrial hydrogen gas. According to Technip's professional cost estimators a market price of 0.08 €/Nm^3 can be used.

Assumptions for the cost simulation

- CAPEX for a 160.000 Nm3/h hydrogen plant are €130.000, CAPEX for a 50.000 Nm3/h hydrogen plant are €50.000, CAPEX for a 15.000 Nm3/h hydrogen plant are €20.000, CAPEX for a 5000 Nm3/h hydrogen plant are €10.000. These assumptions were made by consulting a experiences professional cost estimator and by reviewing the in depth case study
- The assumptions is that an M&S plants has 15% less CAPEX, according to the in depth case study
- The average market price of hydrogen was assumed together with the professional cost estimators.
- The assumptions are that plants have a discount rate from 11% (Sinnot & Towler, 2009).
- The assumption is that the plant from the simulation is operational 240 days per year (Sinnot & Towler, 2009).
- The assumptions are that the OPEX have a linear relationship with plant capacity. This means that the OPEX for plants other than the 160.000 Nm3/h can be found by dividing them with the 160.000Nm3/h capacity.

The scenario; The influence of plant capacity on the 'traditional'/M&S business model trade-off

The scenario is based on a speculation that was found during preliminary research and was first touched upon in Chapter 1 (Background and introduction). This speculation tells that the plant capacity can play a major role for the client to decide for a 'traditional' plant or M&S plant. Namely, it is argued that the share of the OPEX of the plant becomes more important in relation to the CAPEX for increased plant capacities. Furthermore, it is argued that an M&S plant is less efficient then a 'traditional' plant. It is argued that this will result in a trade-off between the importance of the OPEX and CAPEX that is dependent on the plant capacity. The researcher wants to test this speculation and this will therefore be done by developing a 'simulation from a clients perspective'.

This scenario simulation will shed light on the OPEX and CAPEX trade-off between the M&S and 'traditional' business models based on plant capacity.

This scenario will therefore use a plant with a 'large' capacity (160.000 Nm3/h) and a plant with a 'small' capacity (5000 Nm3/h) and run the simulation for both business models. The 'traditional' business model has 'normal' CAPEX but a relatively better OPEX profile. The M&S business model has 'reduced' CAPEX but a relatively poorer OPEX profile. To simulate a poorer OPEX profile (less efficient plant) the assumption is made that more feed is required for the same product (+ 10%) and more energy is required for the same product (+20%).

Results scenario

Table 6: Simulation of cost escalation for 'traditional' and M&S plants for different plants capacities.

Indicator	'traditional' 160.000 Nm3h (*10^6)	M&S 160.000 Nm3h (*10^6)	Delta % (M&S/ Traditional)	'traditional' 5000 Nm3h (*10^6)	M&S 5000 Nm3h (*10^6)	Delta % (M&S/ Traditional)
Total CAPEX	€ 130	€ 110.5	-15%	€ 10	€ 8.5	-15%
Total OPEX (20 years)	€ 269.3	€ 290.5	+8%	€ 8.07	€ 8.17	+1.2%
Cumulative NPV	€ 249.18	€ 262.48	+5%	€ 2.48	€ 3.82	54%
Payback time	3	2	-1	7	5	- 2

Interpretation of scenario results

Table 6 depicts the two extremes from the cost simulation; 160.000 Nm3/h and 5000 Nm3/h. For every cost comparison a column is added that shows the delta percentage (M&S/'traditional'). It is found that, according to the in depth case study, there is a 15% decrease in CAPEX for an M&S plant. Furthermore, due to inefficiencies the OPEX are higher for M&S plants, however, the lower the plant capacity is, the smaller the difference becomes in OPEX. Next, the bottom line (cumulative) NPV indicates that an M&S plant outperforms a 'traditional' plant for plants at least up to € 160.000. However, it can be induced that the larger the plant becomes the smaller the benefit becomes for the M&S plant.

Section 5.5 The Expert interviews

Another important method of data collection during the Case study are the Expert interviews. The goal of these interviews is to collect qualitative data that shows where the 'traditional' and M&S business model differentiate. This information will then be used to develop the Reflected 'list of conditions'. The scope comprises *the understanding of the benefits, costs, drivers and barriers of the M&S business model relative to the 'traditional' business model.* The scope and questions are based on the following topics;

- The current knowledge of the interviewees on the M&S topic.
- Their opinion on the drivers and barriers to choose the M&S business model relative to the 'traditional' business model.
- Their opinion on the costs and benefit for the M&S business model relative to the 'traditional' business model.

The questions in the interview are semi-structured in nature. This means that the topics of the questions are thought about quite well (see points above); however, the questions are open ended. This means that the interviewee is allowed to divert to further elaborate on the questions. This type of interview structure allows the researcher to gather a more broad set of information, which might lead to new topics that he himself has not thought about.

Selection procedures

The core of this information mainly has tactical and strategic purposes (selecting the appropriate business model). For this reason, it is imperative that the interviewees have numerous years of experience in the plant engineering industry. Furthermore, the interviewees should also have experience in acting on a tactical and/or strategic basis. When selecting the interviewees on latter criteria one is bound to ask the 'high-level' and upper management functions (e.g. Managers, Directors, Vice-Presidents). Furthermore, according to (Powell, 1999) and (Creswell, 2012) 5 or 6 interviewees can be deemed sufficient for a single Case study. Moreover, the relative small scope of the research (contrasting two business models) and the homogeneity of the participants (plant engineering representatives) also justifies the use of this relatively small number of interviewees.

Taking into account these selection criteria the author has decided to select the following interviewees; the Vice President (VP) production development, the Vice President execution, the Director estimating and two experienced Project managers. The two VP's and the Director were chosen due to their strategic experience whilst the two project managers were chosen for their more tactical mindset. Table 7 introduces the specific information on the expert interviews

Table 7: Information on expert interviews used in thesis

Interviewee function	Abbreviation (reference in thesis)	Experience (years)	Appendix # summary
Vice President 1	VP1	33	Appendix E
Director	D	30	Appendix A
Project Manager 1	PM1	30	Appendix B
Project Manager 2	PM2	22 & 28	Appendix D
Vice President 2	VP2	32	Appendix C

The Expert interviews are part of the Case study and function as data collection method. For this reason, the interviewees are selected at only one company; the case company Technip. The author contact other companies with the question if they were interested to participate in this research, however, the other companies were reluctant (see Chapter 8 reflection on research).

Chapter 6. Reflected 'list of conditions'

This chapter is the second analysis part of this research. In this chapter the information found in the Case study (Chapter 5) will be analyzed. A new 'list of conditions' will be derived and some conditions will be reflected during this analysis. For this reason it is called; *the Reflected 'list of conditions'*. These 'conditions' will indicate where and how the 'traditional' and M&S business model differentiate from each other. Furthermore, in this chapter the Business Model Canvas (BMC) theory will be applied for further comparing the two business models. This theory will also help to give the readers a more comprehensive and conceptual understanding of 'conditions' that are introduced.

Section 6.1 Approach used for making the Reflected 'list of conditions'

The approach for the development of the Reflected 'list of conditions' is as follows: The results from the case study and the expert interviews are analyzed and the information that differentiates the 'traditional' business model with the M&S business model will be used. This information will be classified as a 'condition'. Next, some 'conditions' from chapter 4 might be revised after reviewing them and reflecting them with information from the case study or expert interviews. Furthermore, the Business Model Canvas theory will be applied at the Reflected 'list of conditions' to bring a more comprehensive and conceptual understanding of the information. Figure 13 gives an indication of the approach in making the Reflected 'list of conditions'.

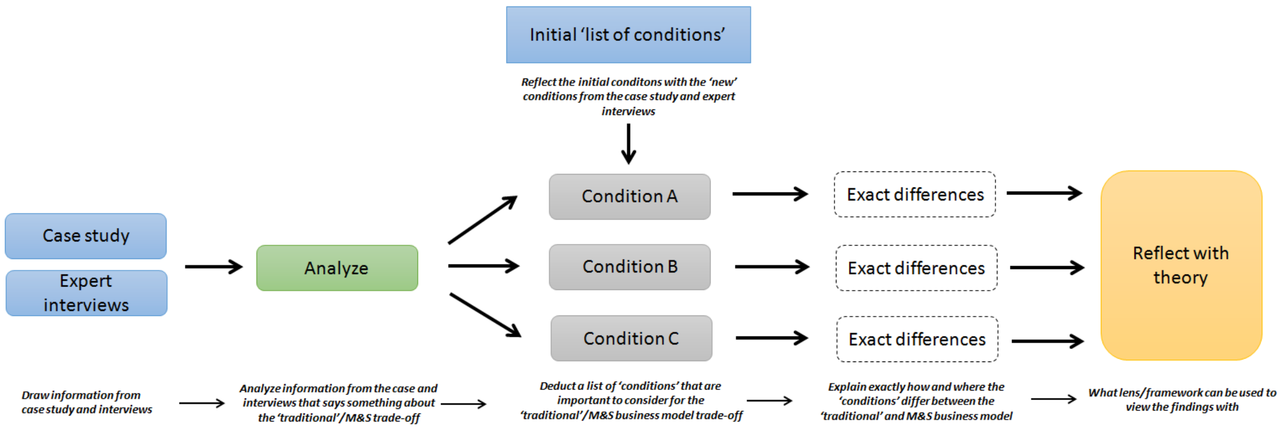

Figure 13: Conceptual visualization of the second analysis part; developing the Reflected 'list of conditions'

In the following section the Reflected 'list of conditions' is introduced. In the following section the information from the case study and the expert interviews will be analyzed and induction will be made to form the 'conditions'. The 'conditions' indicate on where and how the 'traditional' and M&S business model differentiate between each other. The two most important perspectives will be adopted; the plant engineering perspective and the clients perspective. This section will be subdivided into three pieces; (1) 'conditions' that are reflected upon from the initial 'list of conditions' (2) 'conditions' from a plant engineering perspective and (3) conditions from a clients perspective. Every conditions will be reflected upon with BMC theory.

Section 6.2 Reflection on initial 'list of conditions'

This section will introduce some 'conditions' that have already been discussed in Chapter 4. However, information found during the case study and expert interviews required these conditions to be reflected upon, or revised. The 'conditions' are thus introduced in this section in the following manner; (1) briefly introducing and explaining the condition and (2) analysis of *how* the 'condition' differentiates the 'traditional' and M&S business model and (3) reflection with the BMC theory.

Reflected condition 1: Modularity

The condition 'Modularity' was discussed in Chapter 4 thus no further explanation of the definition is required. However, during the Case study chapter (Chapter 5) new information was acquired and for this reason it is necessary that this condition is reflected upon. By reviewing the interviews the following can be induced:

(1) According to the interviewees (PM2, PM1 and VP1) it is required to take into account as many as possible scenarios when developing the modular and standard design. In more specific they argue that several contingencies; like high earthquake resistance (i.e. fortifying the design), varying temperature conditions and adaptable modules (e.g. to adapt to different feed conditions), should be taken into account. According to the interviewees it is imperative to adopt these scenarios into the M&S design. This will be a major extra cost for the M&S business model.

(2) Some of the interviewees (PM2 and PM1) argue that another cost of modular design is the cost of brainstorming. This is especially important for the initial design of an M&S plant. Namely, an M&S plant requires a new mindset on thinking about the design of plants in relation to 'traditional' plants. For example, a 'traditional' plant is a one-off-a-kind mindset, whilst the M&S plant needs repeat job mindset. This means, for instance, that an M&S plant should be adaptable to many circumstances. It is therefore important to have multiple brainstorms session with the different engineering disciplines. This process starts way before the first M&S plant is sold, however, this can be a time consuming and costly process but imperative for the success of adopting the M&S business model.

Reflecting the Business Model Canvas theory on 'Reflected condition 1'

When reflecting 'Reflected condition 1' with BMC theory (Chapter 2.4) it becomes apparent that there is a change in the Key Activities of the M&S business model in relation to the 'traditional' business model. Namely, there is additional effort a required for the first couple of M&S plants to develop different scenarios. This requires additional manpower and hours to develop scenarios, which is a new activity in the M&S business model. Furthermore, the cost of brainstorming is also a 'new' Key Activity for the M&S business model.

Reflected condition 2: Using a fabrication yard

The condition 'using a fabrication yard' was discussed before in Chapter 4 thus no further explanation of the definition is required. However, during the Case study chapter (Chapter 5) this condition showed a new differentiation between the 'traditional' and M&S business model. The results from the interviews and in depth case study were analyzed and the following inductions were made:

(1) According to the interviewees (PM2, VP2, PM2 and D) the possibility to construct a plant in a fabrication yard enables 'location factor benefits'. In turn these 'location factor benefits' enable substantial cost benefits for the M&S business model. Aside from some interviews, the importance of the location factors can also be induced from the *in depth case study*. Namely, in the in depth case study the detailed subcontracting costs were broken down and the relevance of the 'standard man-hours required', 'hourly rate' and 'productivity rate' were explained.

(2) According to (PM2, VP2, PM1 and D) a potential benefit exists in the manipulation of the location factors in case of the M&S business model. Namely, in the case that a fabrication yard is used (to build the modules) this allows the plant engineer to 'pick' from a list of fabrication yards around the world. This allows the plant engineer to choose a fabrication yard that has the most beneficial location factors (i.e. low 'hourly rate' and high 'productivity rate'). On the contrary, in the case of a 'traditional' plant, no fabrication yard is used. This means that the plant engineer is bound to the site of the final plant as indicated by the client. Thus, there might be major financial benefits accrued to the use of a fabrication yard in the M&S business model. By reviewing the in depth case study the importance of the location factor can also be stressed. Namely, in the case of the in depth case study both the M&S plant as well as the 'traditional' plant are built in Rotterdam. However, now imagine that a client wants his plant to be built in the Australian outback (labor in the Australian outback is very expensive). For a 'traditional' plant this would mean that all the work has to be executed on-site in the outback. However, now imagine that the plant engineer can built his M&S plant in the outback, this would mean that at least 80% of the work can be executed in a fabrication yard. When this 80% is executed in a fabrication yard in the Philippines (cheap labor), this can save him substantial cost.

(3) According to (PM2 and D) a barrier of using a fabrication yard can be the condition 'Local labor regulations'. This means that the county in which the plant is built requires a specific quota of labor used from their specific country. Logically, this can be a problem when the fabrication yard that is used does not reside in that specific country. Namely, this will hamper the 'location factor benefits'.

Reflecting the Business Model Canvas theory on 'Reflected condition 2'

When reflecting 'Reflected condition 2' with BMC theory (Chapter 2.4) it becomes apparent that the M&S business model will have a different Cost Structure then the 'traditional' business model. Namely, the potential to use a fabrication yard means that the costs can be 'manipulated' by moving labor to cheap, and efficient, location in the world. When analyzing this reflected condition it becomes clear that the M&S business model will be even more 'cost-driven' then the 'traditional' business model.

Reflected condition 3: Procurement discounts

The condition 'Procurement discounts' was mentioned in Chapter 4 thus no further explanation of the definition is required. Some interviewees (VP2 and VP1) gave information that required the author to reflect on this condition. In Chapter 4 it was indicated that frame agreement with vendors could lower material prices for future M&S plants. However, the following was induced from the case study chapter.

(1) (VP2 and VP1) claim that a barrier exists for this condition. This barrier is imposed by the client. The interviewees claim that sometimes the client inscribes the plant engineer to select vendor from a pre-qualified list. A client can claim this because he himself has frame agreements with certain vendors, or the client is convinced that only certain vendors deliver the quality that meets their standards. The imposing of these so called 'pre-qualified' vendors by the client can act as a barrier to make full use of the 'Procurement discounts' condition.

Reflecting the Business Model Canvas theory on 'Reflected condition 3'

When reflecting 'Reflected condition 3' with BMC theory (Chapter 2.4) it becomes apparent that there is a change in Customer Relationships between the M&S business model in relation to the 'traditional' business model. Namely, when the plant engineer wants to utilize this condition it should apparently have a certain 'good' relationship with the customer so that it is allowed to select from his 'own' vendor list.

Reflected condition 4: 'Learning curve' effect

The condition ‘Learning curve’ effect was mentioned in Chapter 4 thus no further explanation of the definition is required. However, during the Case study chapter (Chapter 5) new information was found that indicated a new difference for this condition between the two business models. The following induction can be made:

(1) According to (VP2 and VP1) the benefits from the ‘learning curve’ effect in the fabrication and in the construction phase can have a barrier. Namely, in both the fabrication and the construction phase the ‘learning curve’ effects are dependent upon a ‘third party’; the vendors, the module fabricators and/or the subcontractors. The problem lies in the fact that not always the same particular ‘third party’ be used. Namely, sometimes a client demands the plant engineer to pick this ‘third party’ from a pre-qualified list (e.g. because of the clients own arrangements). Logically, this will hamper or block the ‘learning curve’ that is built up at a specific fabricator and/or constructer.

Reflecting the Business Model Canvas theory on 'Reflected condition 4'

When reflecting the 'Reflected condition 4' with the BMC theory (Chapter 2.4) it becomes apparent that there is a change in Customer Relationships between the M&S business model in relation to the 'traditional' business model. Namely, just like the 'Procurement discounts' condition it is important for the plant engineer to have a good relationship with his client in which he is allowed to pick his own 'third parties'

Section 6.3 New conditions from a plant engineering perspective

The following section will introduce new conditions which were found and/or can be induced from the case study (Chapter 5). The 'conditions' are thus introduced in this section in the following manner; (1) briefly introducing and explain the condition and (2) analysis of how the 'condition' differentiates between the 'traditional' and M&S business model and (3) reflection with the BMC theory.

Condition 1: Standardization

The condition ‘standardization’ refers to the degree of repeatability that can be reached for a plant. In this thesis the term standardization is referred to as full standardization (i.e. repeat order standardization). The interviewees (PM2, VP2, PM1, VP1 and D) highlighted the fact that the M&S business model can reap major benefits due its standardized nature. Furthermore, the *in depth case study* also provided the researcher with information on the effect of standardization on performance of the M&S business model in relation to the 'traditional' business model. The following differences in business models for this condition can be induced from the interviews and in depth case study:

(1) According to (PM2, PM1, VP1 and D) a standardized design has a higher cost of engineering and coordination for the first M&S plant that is built. They claim that when a plant will be sold ‘standardized’ the design requires more investment to prevent future alterations in the design when there are different location circumstances. This logic can also be derived from the in depth case study which shows that Technip makes a clear distinction between the *first* and n^{th} M&S plant. Also from the in depth case study it is found that the cost of the first M&S plant is slightly higher than the cost of a random ‘traditional’ plant. Thus a drawback of standardization is the higher investment costs which are incurred for the first M&S plant that is built.

(2) According to (PM2, VP2, PM1, VP1 and D) a standardized design can result in lowered engineering cost in the long haul. The interviewees explained that for the n^{th} M&S plant the cost of engineering can be substantially decreased. Their argument was based on the fact that a standardized plant requires no new design cost. When reviewing the in depth case study this logic can also be derived for the n^{th} M&S plant. Namely, from the in depth case study it becomes clear that there is a major reduction in hours required for engineering disciplines (process, piping, internals and E&I), on average 60% for these disciplines. Furthermore, also the procurement functions, construction functions and project management functions are cut in half regarding the hours required according to the *in depth case study*. Thus a major benefit of the condition 'standardization' is that the overall engineering cost can be drastically decreased for n^{th} M&S plant (-+75%)(See *in depth case study*).

Reflecting the Business Model Canvas theory on Condition 1: Standardization

When reflecting condition 1 with BMC theory (Chapter 2.4) it becomes apparent that The dramatic increase of repeatability will probably result in changes in Key Activities and Key Resources in the M&S business model in relation to the 'traditional' business model. Namely, since much less design work is required at the plant engineering home office, this will drastically cut in the 'human' resources for the M&S business model. Furthermore, the standardized nature of an M&S plant also means that the Key Activities will shift away from 'tailor made' engineering to 'repeat job' computer work.

Condition 2: Design variations

The condition 'Design variations' refers to the requirement to alter a design as per client wishes. Design variations can be required for several reasons such as; Fitting it in the layout of an already existing plant (i.e. Brownfield location), fitting the plant to different feed conditions, fitting the plant to different environmental conditions etc. According to (PM2, PM1 and D) this is a potential problem situation for the M&S business model.

(1) According to (PM2, PM1 and D) the request of a client for a variation in the design can be a cost of the M&S business model. Namely, a plant from the M&S business model relies on full standard plant solutions for the client. However, there might be instances when a client requires his plant to be built on a site with novel characteristics that do not fit the 'standard' design requirements. Some of these novel characteristics might be; differences in feed conditions, differences in outside temperature conditions or high risks for earthquakes. Due to these characteristics the client might be unwilling to buy the standard plant or even not be able to function the plant normally. This will thus force the plant engineer, operating an M&S business model, to re-design some elements in the M&S lay-out. This of course goes against the nature of the M&S business model and the additional engineering cost will substantially increase the CAPEX of the M&S plant. However, the M&S plant has not become more efficient then it was with initial 'lower' CAPEX. This means that, in case of adding design variations, the M&S plant becomes more expensive but the OPEX remains 'inefficient' in relation the 'traditional' plant.

Reflecting the Business Model Canvas theory on Condition 2: Design variations

When reflecting with BMC theory (Chapter 2.4) it becomes apparent that the lack of 'design variations' will bring forth a change in Key Activities in the M&S business model in relation to the 'traditional' business model. Namely, an M&S plant will not have the option to apply design variations.

Condition 3: Technological improvements and updating

The condition 'Technological improvements' refers to the requirement to improve the existing plant design. When the conditions 'Technological improvements' holds this might be an extra cost for the M&S business model

(1) According to (VP1 and D) the design of standardized plant will eventually incur some cost required to improve the existing technology or update some other elements from the design. The interviewees mentioned that technology from the plants in their business is fairly mature, this means that not much will really change in their case. However, it must be taken into account that, when dealing with novel or fairly novel technologies, certain technological improvements might require drastic changes to be made in plant design and thus modular structure. This potential requirement of re-thinking the M&S design can entail significant cost and must be taken into account when developing the cost-benefit analysis.

Reflecting the Business Model Canvas theory on Condition 3: Technological improvements

When reflecting with BMC theory (Chapter 2.4) it becomes apparent that technological improvements will bring forth a change in Key Activities in the M&S business model in relation to the 'traditional' business model. Namely, since a 'traditional' is actually prone to continuous improvements of the design. Every new 'traditional' plant is tailor made and there is room for applying the potential new technologies. However, in the standard nature of the M&S plant there is no room for continues improvements. This results in less activity in 'day-to-day' design work, however, this will result in the fact that every now and then the M&S plant needs to be re-evaluated to adopt potential new technologies and to update the modules and design.

Condition 4: Market segment fit

The condition 'Market segment fit' is a condition that refers to the extent to which the incumbent plant engineer's current market segment fits with a potential other market segment. According to the (K and R) this can be a relevant condition. The following differences in business models for this condition can be induced from the interviews and in depth case study:

(1) According to (VP1 and D) the absence of a market segment fit for the M&S plants can block the adoption of the M&S business model. Their argumentation is based on the fact that the incumbent plant engineers often rely on their place in client's existing reference bases for potential future invitation to bid or tender for projects. However, in some cases plants from the M&S business model might be more interesting for a slightly different market segment. As an example, some interviewees argued that the clients of their current 'traditional' hydrogen plants were mostly large refineries. However, they expect that M&S hydrogen plants might be attractive for a slightly different market segment (e.g. smaller applications). In this case the condition 'market segment fit' does not hold. As a result, there will be the need to conduct new marketing studies, educate sales teams and in general make the clients aware of the new M&S plant.

Reflecting the Business Model Canvas theory on Condition 4: Market segment fit

When reflecting with BMC theory (Chapter 2.4) it becomes apparent that there is the potential that the market segment fit will bring forth change in the Customer Segment in the M&S business model in relation to the 'traditional' business model. Namely, as explained in this condition, the M&S plant can attract a customer with different needs then for the 'traditional' plant. This can result in the fact that the M&S business model will address a totally different Customer Segment.

Condition 5: Plant capacity

The condition 'Plant capacity' means to the size, or the throughput, of a plant. The plant capacity is always dependent upon the wishes of the client. According some of the interviewees (VP2 and VP1) the plant capacity is an important condition for both the plant engineer as well as the client to take into account in analyzing the decision between the 'traditional' and M&S business model. The interviewees claim that it's advantageous for the M&S business model to design plants with low capacities. Both the interviewees (VP2 and VP1) as well as the *client cost simulation* have shown that a low plant capacity is preferred for the M&S business model to succeed. By reviewing the interviews and the client cost simulation the following can be induced:

(1) According to (VP2 and VP1), and as made explicit in the client cost simulation, a low plant capacity is an enabler of a more strong tendering position. The interviewees claim that; the lower the plant capacity is, the more attractive the M&S plant becomes for a client. Their line of argumentation was based on the fact that the share of OPEX in relation to the share of CAPEX decreases for lower plant capacities. This argumentation was substantiated and tested in the *client cost simulation* (section 5.4). In short, this cost simulation simulated the costs (cumulative NPV) of acquiring and operating an M&S and 'traditional' plant over 20 years. From this client cost simulation it became clear that for two identical 160.000 Nm3/h plants the delta cumulative NPV was only 5% in favor of an M&S plant, whereas for an identical 5000 Nm3/h plant the delta cumulative NPV was 54% in favor of the M&S plant. Thus, this makes explicit that the lower the capacity the more attractive an M&S plant becomes for the client.

(2) According to (VP2 and VP1), the advantage of the M&S business model during tendering for plants with low capacities also has a downside. Namely, these interviewees argue that plants with a 'low' capacity can also be bound to certain market/customer segments. This means that when an incumbent plant engineer serves a market segment that relies on 'high' capacity plants, the 'Low plant capacity' condition will block the success of this incumbent plant engineer to adopt the M&S business model. The interviewees gave an example from their own market, hydrogen. They claim that the hydrogen market has a large 'plant capacity span', from 200.000 Nm3/h (very large) to 200 Nm3/h (very small). If they choose to adopt the M&S business model they can and should address the market for 'small hydrogen plants to increase the viability of the M&S business model. However, imagine a plant engineer that serves a market that requires plant with capacities of 50.000 Nm3/h or higher. This will result in the fact that their market will act as a barrier, or blocker, for the success of adopting the M&S business model. s

Reflecting the Business Model Canvas theory on Condition 5: Plant capacity

When reflecting with BMC theory (Chapter 2.4) it becomes apparent that the effect of the plant capacity on the CAPEX and OPEX will bring forth change in the Value Proposition and Customer Segments for the M&S business model in relation to the 'traditional' business model. Namely, the trade-off in plant capacities results in a more favorable Value Proposition of an M&S plant for 'low' plant capacities and more favorable for a 'traditional' plant for 'higher' capacities (See Reflected condition 1 from a clients perspective). Furthermore, since M&S plants are more attractive to the clients at lower capacities this can also means that they address different Customer Segment (see Condition 4: Market segment fit)

Condition 6: Module size

The condition 'Module size' refers to the size of the modules which can be used in the M&S design. Some (PM2, PM1 and VP1) have highlighted during their interviews that the module size can play a role in deciding whether to adopt the M&S business model. They claim that the smaller the module size the more likely it is that the M&S business model will be viable. By reviewing the interviews and the following can be induced:

(1) The interviewees (PM2, PM1 and VP1) claimed that the smaller the module the less transportation risk is involved for plants from the M&S business model. According to them typical transportation risks are; damaging of the modules and delay in the transportation delivery time. These risks are always present, also during the construction of a ‘traditional’ plant; however, these risks are always greater for a modular design. The transportation of larger modules (i.e. larger than container size) becomes a difficult task because it always requires special transportation. This special transportation often means that parts of the module are exposed to the environment, thereby increasing the risk of damaging them. However, the interviewees argue that when a module can fit in container size, these risks can be drastically reduced.

(2) The interviewees (PM2, PM1 and VP1) claim that all modules larger than container size require additional cost of transportation which has to be taken into account for the M&S business model. Their argument is based on the fact that all modules larger than a container require special transportation. Special transportation refers is required when a load cannot be dismantled into units that exceed the limitations (e.g. weight or size) of truck and/or train transport. This special transportation is more expensive than normal transportation and is thus and additional cost of the M&S business model.

Reflecting the Business Model Canvas theory on Condition 6: Module size
When reflecting with BMC theory (Chapter 2.4) it becomes apparent the effect of the module size will result in change in the overall risk for the M&S business model and on the Value Proposition. Namely, depending on the module size, the risk of transport increased for the plant engineer of an M&S plant. Furthermore, this risk directly results in increased risk for the client in the form of potential schedule delays.

Condition 7: Modular transferability

The condition 'Modular transferability' refers to the potential to interchange certain modules between different types of plants. (VP2) Indicated during the interviews that there are some benefits accrued to the potential to 'interchange' certain modules between different types of plants. In general, the interviewee claimed that the higher the modular transferability is, the more viable the M&S business model becomes.

(1) According to (VP2) some modules exist that are 'generic' and are usable for different types of plants. (VP2) argues that some modules consists of a typical process that is common in many different plants. As example he argues that the feed for an Ammonia plant and Hydrogen plant are similar. This could mean that - in case a individual module was built for the 'feed entry' process - this module could be interchangeable and transferable between both the Ammonia and Hydrogen plant. From the latter it becomes clear that in case a certain 'generic' module already exists from a previous plant - which can also be used for plants from the M&S business model - this will save front-end costs. Moreover, the modules designed specifically for the M&S plant might also be used in all sorts of different plants in the future (e.g. when an M&S hydrogen plant is developed the feed modules might also be used for a future ammonia plant). Thus, the potential to 'transfer' modules from previous plants to an M&S plant, or from an M&S plant to a future 'new' modular plant will save front-end costs in both cases.

Reflecting the Business Model Canvas theory on Condition 7: Modular transferability
When reflecting with BMC theory (Chapter 2.4) it becomes apparent that the effect of transferable modules will bring forth a change in Key activities and Key resources. Namely, the potential to transfer and reuse particular modules will reduce engineering activities in the front-end for the M&S business model. Furthermore, just like in Condition 1; standardization, the potential to reuse modules will ensure that less 'human' resources are required, thereby potentially losing 'tacit knowledge'. Finally, some elements in the Cost structure might have to be adapted since front-end engineering cost will go down when fully transferring modules.

Section 6.4 New conditions from a clients perspective

This section will introduce the 'conditions' that are relevant from a clients perspective. In this section new 'conditions' will be added and the conditions from Chapter 4 will be reflected upon. This section will thus introduce the conditions of relevance from a clients perspective by using the Case study data (Chapter 5). The conditions will be introduced as following; (1) briefly introducing and explain the condition and the (2) an analysis of how the 'condition' differentiates between the 'traditional' and M&S business model and (3) reflection with the BMC theory.

Reflected Condition 1: Investment costs

The condition ‘investment costs’ is not new, however, new insights were found in the Case study chapter (Chapter 5). The following inductions can be made for this condition:

(1) According to the in depth case study the cost of developing a plant in the M&S business model is lower for the n^{th} M&S plant. The interviewees (PM2, VP2, PM1, VP1 and D) argued that this was due to the fact that much less home office costs are required for a ‘repeat job’ plant. Less home office hours means less engineering costs. According to the in depth case study this saves about 15% on a 15.000 Nm^3/h plant.

(2) According to some interviewees (PM2, VP2, PM1, VP1 and D), the condition ‘Using a fabrication yard’ is also very beneficial for the client. Namely, some fabrication yards, depending on the location, require lower costs to produce modules. If a beneficial location is found this might save substantial fabrication costs which also means that the plant can be offered at a lower cost.

Reflecting the Business Model Canvas theory on Reflected Condition 1: Investment costs
When reflecting with BMC theory (Chapter 2.4) it becomes apparent that the Value Proposition becomes more attractive for the client for the M&S business model. Namely, the decreased design cost and the potential to produce a plant in a 'cost beneficial' location can result in a better price offering of an M&S plant in relation to a 'traditional' plant.

New condition 1: Energy efficiency

The condition ‘Energy efficiency’ is a new condition that can be derived from the Case study chapter (Chapter 5). The rationale from this condition was first mentioned during the interviews. Namely, (VP1 and VP2) argued that a big driver for clients to choose a plant from the ‘traditional’ business model was the impact of ‘over-engineering’. ‘Over-engineering’ means that the design is optimized as much as possible in order to gain some extra percentages in efficiency increase. However, this ‘over-engineering’ is not an option for the client in the M&S business model. The following can be induced about this condition for the client:

(1) According to (VP2 and VP1), a major cost for clients from the M&S plant is the energy consumptions (e.g. utilities and feed). According to (VP2 and VP1) the energy efficiency is lower for an M&S plant relative to a 'traditional plant'. This is due to the fact that a standard plant from the M&S business model is designed to fit multiple circumstances and conditions. This one-size-fits-all concept (i.e. M&S plant) means that it cannot be 'tweaked' to fit different location and environmental circumstances (e.g. feed quality differences or environmental temperature conditions). This condition was also made explicit during the client cost simulation (Chapter 6).

(2) According to (VP2 and VP1) the relevance of energy efficiency diminished for lower plant capacities. This trade-off was already explained in the condition Plant capacity. In short, the lower the plant capacity is the less relevant is the share of OEPX relative to CAPEX. Put differently, a driver for the client to choose an M&S plant would be when the client requires a plant with a low capacity.

Reflecting the Business Model Canvas theory on New client Condition 1: Energy efficiency

When reflecting with BMC theory (Chapter 2.4) it becomes apparent that there is a difference in Value Proposition for this condition between the M&S business model and the 'traditional' business model. Namely, the energy efficiency, a part of the OPEX, is lower for an M&S plant. It must be noted, however, that the relevance of the OPEX is dependent upon the plant capacity. Namely, the lower the plant capacity is the more important the CAPEX will be and the less important the OPEX will be.

Chapter 7. The assessment framework

Up until now this research has delivered substantial theoretical information on the differentiation between the 'traditional' and M&S business model (Chapters 5 and 7). However, in order to make this information more 'tangible', or 'practical', the assessment framework is developed. The assessment framework will be practical instrument that can be used to tap the knowledge of the plant engineering decision makers and derive an overall advice based on a number of respondents. The advice can go two ways; plant engineers are advices to either (1) stay with the 'traditional' business model or (2) further invest resources in the M&S business model. In short, this chapter will elaborate on the development of the assessment framework, it will introduce the assessment framework and it will explain how to interpret the assessment framework.

Section 7.1 Development of the assessment framework

In order to derive from this theoretical research a practical instrument an appropriate assessment framework was chosen. The core of the assessment framework will be a data collection method that can be used to gather the knowledge from the plant engineering decision makers and transform it into more quantitative and statistical data. The assessment framework will be based on the information gather in Chapter 5 and 7.

Selecting the appropriate framework

According to (Sekaran & Bougie, 2013) data can be collected in numerous ways such as; different types of interviews, focus groups, questionnaires, observations etc. In order to choose the appropriate data collection method for this assessment framework the requirements have to be understood. The requirements of the assessment framework were based on the assumption that it will serve as a 'pre-assessment' framework that can initiate a more elaborate evaluation of the decision to go for the M&S business model. For this reason, the framework must be (1) easy to use, it must be (2) inexpensive to use and it should, preferably, (3) gather as much data from as many people as possible in a relatively short time. By taking into account these requirements and reflecting it with other data collection methods (Sekaran & Bougie, 2013), the author decided that a questionnaire was the appropriate data collection method.

Selecting the appropriate type of questions

As mentioned in previous paragraph the data collection method for the assessment framework will be a questionnaire. The questions from the questionnaire will be based on the information from Chapter 5 and 7 ('list of conditions'). According to (Ackroyd & Hughes, 1981) a questionnaire can have three types of question; factual questions, perceptual questions and exploratory questions. Within this questionnaire two types of question lists are developed; (1) a question list that gathers factual and descriptive information, seeking hard 'evidence' for the M&S business case and a (2) a question list that gathers perceptual information, seeking the attitude of the respondent on the subject matter. The ***factual questions*** are questions that require an answer based on facts and *descriptive information*. Thus, these are answers that should tap the *knowledge* of the plant engineering decision maker. The outcome of the *factual* question list can substantiate the use of the 'traditional' or M&S business model based on descriptive information and facts. The ***perceptual questions*** are questions that require a perceptual answer based on *subjective information*. Thus, these are answers that should tap the *attitude* of the plant engineering decision maker. The outcome of the perceptual *question* list captures expectations and perceptions of a particular plant engineering company thereby creating an image of potential future success of the M&S business model.

Furthermore, there are many measurement methods that can be used for measuring the answers to question in a questionnaire (e.g. yes/no, numerical scales etc). However, according to (Sekaran & Bougie, 2013) the most widely used method of measurement is '5 point Likert scale'. The '5 point Likert scale' has many benefits. At first, it allows easy interpretation of results and further potential mathematical analysis. Secondly, it does not force the participant to take a stance but allows more degrees of freedom. Thirdly, the Likert scale is easily understood by participants. Finally, the Likert scale is quick, efficient and inexpensive. For this reason, the questionnaire will be based on a '5 point Likert scale'.

Weighting of the questions

The ***factual questions*** have a higher weight then the ***perceptual questions***. Namely, since the *factual questions* are based on descriptive information they indicate whether the M&S business model is beneficial or whether they should stay with the 'traditional' business model *based on 'factual' evidence*. The *perceptual questions* should only be used to break a potential 'tie' when the result of the *factual questions* fail to deliver a concrete advice. When a tie occurs the outcome to the *perceptual questions* will indicate how the future might develop according to plant engineers subjective information and it will indicate the overall stance of the plant engineers on M&S.

Transforming the conditions into questions

The questions are based on the information from chapters 5 and 7. The conditions were 'transformed' by critically reviewing all of them, understanding the effect that the conditions has on the M&S business model and based on that deriving questions. Table 8 and 9 shows a table in which it is indicated what conditions were used in what questions. Furthermore, Appendix F and G is devoted to an extensive elaboration and argumentation on how the conditions were 'transformed' into the *factual questions* and *perceptual questions*.

Table 8: Cross indication of what conditions prevail in what factual questions

		Factual questions																			
		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	
All conditions	**Initial conditions (Chapter 5)**																				**#**
	Condition 1 Modulairty		x				x														2
	Condition 2 Procurement discounts				x	x							x								3
	Condition 3 Learning curve	x											x								2
	Condition 4 Parallel manufacturing								x												1
	Condition 5 Using fab yard								x		x										2
	Condition 6 Owning fab yard											x									1
	Condition 7 Company commitment									x											1
	Reflected conditions (Chapter 7)																				
	Reflected condition 1 Modularity						x														1
	Reflected condition 2 Using fab yard										x										1
	Reflected condition 3 Proc discounts							x													1
	Reflected condition 4 Learning curve							x													1
	New conditions (Chapter 7)																				
	Condition 1 Standardization	x		x									x								3
	Condition 2 Design variations													x							1
	Condition 3 Tech imprv.														x						1
	Condition 4 Market seg fit																x				1
	Condition 5 Plant capacity															x					1
	Condition 6 Module size																	x			1
	Condition 7 Modular transf.																		x	x	2

Table 9: Cross indication of what conditions prevail in what perceptual questions

		Perceptual statements																	
		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	
All conditions	**Initial conditions (Chapter 5)**																		#
	Condition 1 Modulairty		X																1
	Condition 2 Procurement discounts			X	X														2
	Condition 3 Learning curve					X	X	X											3
	Condition 4 Parallel manufacturing								X										1
	Condition 5 Using fab yard									X									1
	Condition 6 Owning fab yard																		
	Condition 7 Company commitment										X								1
	Reflected conditions (Chapter 7)																		
	Reflected condition 1 Modularity		X																1
	Reflected condition 2 Using fab yard									X									1
	Reflected condition 3 Proc discounts				X														1
	Reflected condition 4 Learning curve							X											1
	New conditions (Chapter 7)																		
	Condition 1 Standardization											X							1
	Condition 2 Design variations												X						1
	Condition 3 Tech imprv.													X					1
	Condition 4 Market seg fit														X				1
	Condition 5 Plant capacity															X			1
	Condition 6 Module size																X		1
	Condition 7 Modular transf.																	X	1

Section 7.2 Introducing the assessment questionnaire

This section introduces the assessment questionnaire. As mentioned above this questionnaire has two parts; the ***factual questionnaire*** and the ***perceptual questionnaire***. The *factual questionnaire* consists of 19 questions that need to be answered on a 5 point Likert scale based on several scale items (e.g. numerical, frequency and knowledge of action). The *perceptual questionnaire* consists of 16 statements that need to be answered on a 5 point Likert scale based on the level of agreement. The *factual questionnaire* has higher weight then the *perceptual questionnaire*. Therefore, in case that the *factual questionnaire* has a 'high enough' result the perceptual questionnaire is much less relevant (further explained in 'Interpreting the results').

Furthermore, the assessment questionnaire should be filled in by the employees of the plant engineering company under consideration. Most questions and statements in the questionnaires requires a broad and in-depth understanding of the company and his strategies (e.g. contract strategies, market segments served, regulations in other countries, strategic design issues). For this reason, it is advised to select relatively experienced plant engineering employees who are familiar with tactical and/or strategic decision making within the organization.

The factual questionnaire

Table 10 introduces the ***factual questionnaire*.** In table 10, for each of the questions the responded should circle the answer that best approaches the correct answer (according to his best knowledge). The questions need to be answered on a 5 point Likert scale. Questions and their measurement scale vary from numerical, frequencies, knowledge of action (e.g. to what extent...) and percentages.

Table 10: The factual questionnaire

FACTUAL QUESTIONS	Please circle the box that best approaches the correct answer				
1. The number of M&S plants that could potentially be sold is (answer with best knowledge of current market and plant engineers situation) ?	0	1-2	2-3	4-6	6+
2. How much experience does the company have with modularity? (has it been done before?)	None	Little	Average	Much	Very much
3. How much experience does the company have with standardization? (has it been done before?)	None	Little	Average	Much	Very much
4. What percentage of the M&S plant can be procured by making use of *current/existing* frame agreements/contracts with vendors?	0%	25%	50%	75%	100%
5. Which percentage of the M&S plant can be constructed by making use of *current/existing* frame agreements/contracts with subcontractors?	0%	25%	50%	75%	100%
6. What percentage of modularization will be applied for the M&S plant?	0%	25%	50%	75%	100%
7. How often do you encounter clients that impose you to select from 'pre-qualified' vendor and/or subcontractor'?	Never	Seldom	Sometimes	Often	Very often
8. What part of the M&S do you expect to built in a fabrication yard?	0%	25%	50%	75%	100%
9. The overall view of this plant engineering company and his employees on the M&S business model is	Very negative	Negative	Neutral	Positive	Very positive
10. What is the chance that a fabrication yard can be chosen with a relatively beneficial hourly rate and labor productivity for a particular M&S plant?	0%	25%	50%	75%	100%
11. To what extent do countries that you operate in impose regulations with regard to labor quotas in that particular country?	Very small	Small	Normal	Large	Very large
12. What percentage of standardization will be applied for the M&S plant design?	0%	25%	50%	75%	100%
13. What percentage of the M&S plant will be open for (small) design variations as per client wishes?	0%	25%	50%	75%	100%
14. How often are technological improvements or 'design updates' required for the main technology in the M&S plant?	Never	Seldom	Sometimes	Often	Very often
15. What will be the *relative* plant capacity (throughput) of the M&S plant design? (relative to plants with the same	Very small	Small	Average	Large	Very large

technology)

16. To what extent is the current customer/market segment (for 'traditional' plants) similar to the segment used for an M&S plant?	Very small	Small	Normal	Large	Very large
17. What will be the average size of modules in the M&S plant design? (where very small is container size and very large is a full 'small' plant as one module)	Very small	Small	Normal	Large	Very large
18. To what extent can individual modules from an existing ('old') design be used in the 'new' M&S plant design?	Very small	Small	Normal	Large	Very large
19. To what extent can the individual modules from the 'new' M&S plant be applied in the design of another modular plant?	Very small	Small	Normal	Large	Very large

The perceptual questionnaire

Table 11 introduces the ***perceptual questionnaire***. The questions in table 11 are based on a 5 point Likert scale that uses a measurement scale based on 'level of agreement'. This scale measures the *attitude* or *perception* of the respondent to certain statements. The perceptual questions are considered relevant when the factual questionnaire did not bring clarity.

For each of the questions below, circle the response that best characterizes how you feel about the statement, where: 1 = Strongly disagree, 2 = Disagree, 3 = Neither agree or disagree, 4 = Agree, and 5 = Strongly agree

Table 11: The perceptual questionnaire

PERCEPTUAL/EVALUATIVE STATEMENTS	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
1. We would probably sell more M&S plants then we sell 'traditional' plants.	1	2	3	4	5
2. It will be relatively easy to maximize modularization for the M&S plant.	1	2	3	4	5
3. I think that setting up frame contracts with vendors for the M&S plant will not be a problem in the future.	1	2	3	4	5
4. I think that setting up frame contracts with subcontractors for the M&S plant will not be a problem in the future.	1	2	3	4	5
5. We would be able to often use the same vendor for the procurement of the M&S plant.	1	2	3	4	5
6. We would often be able to use the same module fabricator for the construction of the modules of the M&S plant.	1	2	3	4	5

7. We would often be able to use the same subcontractor for the construction of the M&S plant.	1	2	3	4	5
8. We would be able to control the CSU of the M&S all the plants ourselves.	1	2	3	4	5
9. Since the M&S plant is built in a fabrication shop we can manufacture many modules in parallel.	1	2	3	4	5
10. There will be no difficulties in bringing forth the 'cultural change' for adopting the M&S business model and gaining enough company commitment.	1	2	3	4	5
11. Standardization will save the company substantial costs in the development of subsequent plants .	1	2	3	4	5
12. Applying design variation in the M&S plant design will have a small impact on overall costs.	1	2	3	4	5
13. Applying 'technological improvements' or 'design updates' will have a small impact on overall costs.	1	2	3	4	5
14. The resources required (time and money) to adjust to the customer/market segment for M&S plants are small.	1	2	3	4	5
15. There is enough potential in the market to sell our relatively 'low capacity' M&S plants.	1	2	3	4	5
16. It is relatively easy to transfer, or interchange, generic individual modules between different plant designs.	1	2	3	4	5

Section 7.3 Using the assessment questionnaire

The assessment questionnaire is first step in evaluating whether to stay with the 'traditional' business model or further research the potential of the M&S business model. The assessment questionnaire requires a broad and in-depth understanding of the plant engineering company and his strategies (e.g. contract strategies, market segments served, regulations in other countries, strategic design issues). For this reason it is very important that the questionnaire is filled in by experienced plant engineers that preferably have experience in tactical and/or strategic decision making. In order to increase the reliability of the instrument it is also preferred to use as much respondents as possible. Due to time constraints this assessment questionnaire has not been validated with regard to the true number of respondents required.

Interpreting the results

A caveat in the interpretation the results is the lack of validation of this assessment questionnaire. Time constraints withheld the author to validate both of the questionnaires. The lack of this validation mostly hurts the weighting of the questions. For this reason, the assessment questionnaire was divided in two parts; the *factual questionnaire* and the *perceptual questionnaire*. Since the results of the factual questionnaire are based on objective information they are deemed to have a higher validity and thus higher weight. The results of the perceptual questionnaire are based on subjective information and are therefore deemed to have a 'lower' validity and thus a lower weight. For this reason, the initial weighting system is based on the differentiation between the factual and the perceptual questionnaires. The perceptual questionnaire should only be used in case of a 'tie' in the factual questionnaire.

As mentioned above, the individual questionnaires still lack a weighting system that classifies when (i.e. at what score, for what answers) the result is *pro the 'traditional' business model* and when it is *pro the M&S business model*. A real and fully validates weighting system for this assessment questionnaire is beyond the scope of this thesis. However, the author has put some effort in the development of an *'initial weighting classification system'.* This *'initial weighting classification system'* differs between the *factual* and *perceptual questionnaires* and it can be explained as follows;

- For the *perceptual questionnaire* this system is straightforward. Namely, the statements are formulated in such a way that - in case the respondent 'agrees' - it is a positive outcome for the M&S business model. A positive outcome (pro the M&S business model) to a single statement would be when the respondent 'agrees' or 'strongly agrees'. The outcome of the full *perceptual questionnaire* would be positive when 9 or more statements are 'agreed' or 'strongly' agreed upon (i.e. more than 50% of the statements). Appendix G gives the argumentation *why* a statement is pro M&S or pro 'traditional'.
- For the *factual questionnaire* the system is a bit more complicated. In Appendix F the author has made arguments and discussed what answers in the factual questionnaire are positive for the M&S business model, this can be found under the header *'initial weighting classification'.* In case that the outcome of more than 10 *factual questions* (more then 50%) are *pro the M&S business model* it can be concluded that that particular questionnaire is *pro the M&S business model.* All other cases might (1) be a 'tie' or (2) might be *con the M&S business model*. In this case it is advises to make use of the perceptual questionnaire to 'gauge' the overall perception of the plant engineering decision makers.

Section 7.4 Final remarks on the assessment questionnaire

From the problem statement it became clear that the plant engineering industry lacks a tool with which they can assess the trade-off between the 'traditional' and M&S business model. In anticipation of this problem this research was devoted to researching *what conditions, or factors, differentiated between the two business models*. From these condition a practical tool was developed by the author; *the assessment questionnaire*. This assessment questionnaire is - with the authors best knowledge - the first tool that addresses this evaluation/assessment. It is thus a first step in *exploring* the trade-off at hand, and it probably *needs further 'refining' to allow decision making purely on basis of this tool*. For this reason, this questionnaire can be seen as a 'pre-assessment' framework, a first step in evaluating whether to stick with the 'traditional' business model or put more time and effort in researching the viability of the M&S business model.

Chapter 8. Reflection on research

This chapter will be the reflection on this research project. The reflection is an important part of the research process since it allows the researcher to learn from his experience and put the research in a perspective in hindsight. This chapter will therefore reflect on the how the overall process of research went in hindsight. There will be highlighted want went as expected and good and what didn't went as expected and less good during the research process. The reflection in this chapter is built up as follows; The author will briefly discuss the most important data collection methods, theories used and the deliverables. The author will then indicate their limitations and potential direction for future research.

The theory used; The Business Model Canvas (BMC)

In Chapter 2 of this research the author devoted the last section to the selection and introduction of a relevant theory that could be helpful for 'easy analysis'. The BMC was selected for two reasons; At first, (1) the BMC was deemed practical in use and it allowed for easy and direct comparison of different business models, this is a benefit for the author. Secondly, (2) the BMC offers a framework for the readers which allows them to gain conceptual and comprehensive understanding of the information from the analysis, this is a benefit for the reader.

When reflecting on the BMC and its use during this research the following can be said; When referring to the reasons - mentioned above - on why the BMC was selected, the author is satisfied with the outcome. The BMC is used in Chapters 4 and 6 - where the 'lists of conditions' are introduced - and the information from every condition is reflected with the BMC. This was fairly practical to do and in this way the two business models under consideration could be easily and directly compared. Furthermore, for the readers of the report that wish the quickly 'scan' the results and information the BMC indeed offers a 'simplified' framework for easy understanding. Thus, in this sense the BMC offered for what the author has selected it.

However, the author also wishes to address some limitations and directions for potential further research. At first, the author finds that the BMC theory is a little slim and misses some 'depth' for a proper analysis of data. The BMC is really actually a model that introduced terms and offers a framework to differentiate business models, this is a limitations of the BMC. Future researchers might be interested in using a theory that allows the business models to be analyzed with a more 'in depth' and broad view. As example, during the selection of the BMC, in Chapter 2, the author mentioned Porters Five Forces theory. This is a theory that can be used to analyze a business strategy and its competitive environment. Analysis with this theory might give more clarity and insight regarding what business model is best for the plant engineer.

The use of the Literature

In Chapter 1 the author mentioned the data sources that would be used for this research. A major data source was literature and the method of data collection and analysis was a literature review. The literature was used for several purposes in this research; (1) *preliminary information gathering*, (2) creating a *(theoretical) background* and as (3*) general data source*.

When reflecting back on the literature review for the *preliminary information gathering* step the author is positive. The preliminary information gathering started in November 2014 when the author committed to the current research problem. Looking back this activity went well overall. The search for literature was somewhat difficult. The author found the search for literature difficult because only a few articles were found that truly addressed the subject at hand. On the one hand this emphasizes the relevance and novel nature of the topic at hand. On the other hand since only a few authors have written about the topic this can harm the reliability of the overall problem. However, during some discussion with industrial experts the author was convinced that the problem was indeed relevant in the incumbent plant engineering industry.

Reflecting on the literature review for creation of a *theoretical background* (Chapter 2) the author was positive. The background gathering started at the beginning of February 2015 and the goal was to obtain information that distinguished the incumbent plant engineering industry. The author introduced what actually is meant with a 'traditional' business model, what the motivation is for M&S, where M&S comes from (theoretically) and how other industries deal with this development. Information on this background was found easily and there were no limitations for this. Furthermore, the author also used this chapter to select and introduce a theoretical framework for 'easy analysis' which was also fairly easy to find with a literature review

When reflecting on the literature review used as *general data source* the author is overall satisfied but some limitations were found. The author is satisfied regarding the approach of partially using academic articles and partially using practical articles. The information found in several articles has substantial overlaps with each other which means the information is probably reliable. However, some limitations during this literature review were found. Namely, the author found only found two articles that exactly 'hit the spot' regarding the problem statement. Other articles were, for instance, from another domain (e.g. construction or steel plant building etc.) or they only discussed modularity without the standardization. The author thinks this is due to the fact that M&S is a fairly new strategy in the plant engineering industry. From experience the author knows that other major companies are in fact investing in M&S, however, they do not release any information due its strategic significance. Furthermore, the author thinks that the 'lists of conditions' from Chapter 4 and 6 can definitely be used in future research as data source that differentiates the 'traditional' and M&S plant engineering strategies.

The use of the Case study

The second data source that was used to extract information from was the Case study at Technip. Three methods of data collection were used during the case study at Technip; (1) In depth case study, a (2) Client cost simulation and (3) Expert interviews.

Reflecting on the *in depth case study* the following can be said; Overall, the *in depth case study* provided sufficient information to analyze and draw conclusions from. However, there are a few limitations that exist in the in depth case study. The *first limitation* lies in the ability to fully generalize the findings in the in depth case study. Namely, the *in depth case study* is based on only *one* company (Technip) and *one* technology (Hydrogen). For this reason, it must be taken into account when interpreting the data that the conclusions could vary for a different company and a different technology. The *second limitation* exists in the scenario set-up of the in depth case study. Namely, since only *one* scenario set-up was created it could mean that this particular scenario is either a 'best case', a 'base case' or a 'worst case' scenario. This scenario was developed in close coordination with professional cost estimators from Technip. But, for example, this scenario did not take into account the cost of cultural change or the cost that arise due to cultural barriers. Another example is that this scenario assumed that the M&S plant has to be designed from scratch and no other items, modules or other pre-work could be transferred from previous projects whatsoever. These are just two examples of potential scenarios which have not been taken into account but that could have resulted in a different outcome of the *in depth case study*.

When reflecting back on the use of the *Client cost simulation* the author is positive overall. The *Client cost simulation* was developed after some notions during the *preliminary information gathering* and the *Expert interviews* in which some claimed that a correlation existed between some variables (See section 5.4). The author obtained some data from databases at Technip and subsequently simulated the events that were said to correlate. The outcome was indeed what was expected and the simulation was a success overall. A limitation might exists in the fact that a simulation was developed for only *one* technology and no sensitivity analysis was performed.

When reflecting on the *Expert interviews* the following can be said; The *Expert interviews* provided data that had substantial overlap with the information found in the *in depth case study*, *Client cost simulation* and *(second) Literature study*. In addition, substantial overlap was found in the answers given by the different interviewees. For this reason, the author finds that the data can be deemed reliable. The author is positive over the interview since they tap the knowledge of experienced plant engineers that is *not only aimed at one technology*. The plant engineers answer the questions with a more broad perspective and knowledge of the plant engineering industry. For this reason, findings from the interviews may therefore be more easily generalized. A limitation might exist in the sample size (5 interviews) of the *Expert interviews*. In Chapter 1 he author explained that some referenced indicated 5 to 6 interviewees are sufficient for a case study method. However, in hindsight the author believes that more interviews would be better to increase the reliability of the results.

Deliverable; The 'list of conditions'

The first deliverable in this report was the 'list of conditions'. The 'list of conditions' consists of the Initial 'list of conditions' (Chapter 4), which is derived from the (second) Literature study data source, and the Reflected 'list of conditions' (Chapter 6), which is derived from the Case study data source. Together they are simply; the *'list of conditions'*. Overall, the author is positive over the development of the 'list of conditions'. Both data sources highlighted topics with good overlap which indicates the data is probably reliable. Since the topic of M&S is fairly novel the author thinks that his 'list of conditions' can be used in future research as reference. The 'list of conditions' can provide a future researcher with information about; (1) major differences between 'traditional' and M&S strategies in plant engineering, (2) the most important definitions used and (3) the most relevant articles that can be found on the topic.

Deliverable; The assessment questionnaire

The second deliverable in this report was the assessment questionnaire. When reflecting on the assessment questionnaire the author is positive, but has some notions about it. At first, the author is positive since, at this moment, the industry totally lacks a practical tool that can help with assessing a potential switch from business models (i.e. 'traditional' to M&S). The assessment questionnaire developed in this research is based on *limited information* and *lacks validation*. For this reason, the assessment questionnaire should be seen a *first cut*, or 'pre-assessment' framework. The results of the assessment questionnaire could therefore *not serve* as a definitive answer the trade-off between the 'traditional' and M&S business model, this is the *first limitation* of the assessment questionnaire. However, the results of the assessment questionnaire *could serve* as a first step in evaluating whether the plant engineer should stay with the 'traditional' business model or whether he should put more time and effort in researching the viability of the M&S business model.

Furthermore, the author currently applied only a basic weighting system. Factual questions have a higher weight than the perceptual questions. This is the *second limitation* of the assessment questionnaire. Namely, the weighting system can be expanded and elaborated, maybe even on a *per question basis.* However, due to lack of time the author was unable to perform further research on the weighting systems of the assessment questionnaire. Thus, a *direction for future research* is the expansion of the weighting system of the assessment questionnaire. One example is that future researchers can use *Q-methodology,* which allows peoples subjectivity to 'order' the questions and so add weights per question.

Finally, the author believes that the assessment questionnaire needs further validation. Currently, the assessment questionnaire is not validated and this means that the results are not fully valid. This is the third limitation of the assessment questionnaire. Thus, a *direction for future research* should be the next step in validation of the assessment questionnaire. As example, future researchers could validate the instrument by checking the results of 'old'/previous projects and see how it correlated with the conditions/criteria from the assessment questionnaire. This should be checked for several projects; modular, stick-built and standardized if possible. A higher correlation between the conditions and the results of the 'old' projects are steps in validation for the assessment questionnaire.

Chapter 9. Conclusions

In this chapter conclusions will be drawn from the information and analysis found and developed in this research. The conclusions will systematically be drawn by reviewing the sub-research questions and answering them as precise as possible.

Sub-RQ 1: *What relevant information can be found on the incumbent plant engineering industry and their current 'traditional' business model?*

Relevant information was found to be information on the current incumbent plant engineering industry. Information was provided on the most relevant actors that the incumbent plant engineers deals with; The clients, the vendors and the sub-contractors. Furthermore, the phases of a plant engineering project were discussed; engineering, procurement and construction. Per phase the activities and most important were explained. Next, the authors found it important to explain exactly what it understood under the 'traditional' business model. In short, the 'traditional' business model is characterized by (1) the possibility to tailor make the plant as client and (2) the stick-built nature of constructing the plant.

Sub-RQ 2: *What is the M&S business model and what role does it have in related industries?*

The modularization and standardization (M&S) paradigm originates from the supply chain literature. Academic literature describes that M&S is a method to move away from a full engineer-to-order strategy to a more make-to-order type of strategy. Theory argues that by doing this firms give up flexibility for reduced costs and speed of development. Other industries such as auto manufacturing and ship building already widely apply the M&S paradigm. However, the plant engineering industry stays behind due to the fact that the product volume is low and product complexity is high.

Sub-RQ 3: *What relevant theories can help with answering the research question?*

The Business Model Canvas theory will be used as lens to view the findings with. By applying this theory a comprehensive and conceptual understanding is offered to the readers and the future researchers in this topic. Furthermore, the BMC will also offer a 'simplified' framework is offered for further analysis in this research (e.g. for developing the *assessment questionnaire*).

Sub-RQ 4: *What conditions that play a role in the M&S/'traditional' business model trade-off can be found when analyzing the literature?*

The full *Initial 'list of conditions'* can be found in Chapter 4. A summary of this 'list of conditions' combined with a brief argumentation is given below. First the conditions from a plant engineering perspective will be introduced then the conditions from a clients perspective.

- **Modularity** – Refers to the condition where modular design is used in the business model. A modular design means that the design is ‘split-up’ in modules.
    - Modularity acts as an enabler of standardization, when used both they have a synergetic effect
    - The cost of structural steel is higher for a n M&S plant
    - The cost of transportation is higher for an M&S plant
    - The cost of coordination and supervision is higher for a modular plant

- **Procurement discounts** - Refers to the potential of obtaining discounts on materials from the supply side?
    - A good buyer-supplier relationship is an enabler of potential procurement discounts
    - A barrier of procurement discounts are pre-qualified vendor lists assigned by the client
    - Due to standard materials from the M&S business model a framework agreement can be set-up with vendors to deliver these standard materials against reduces tariff.
- **'Learning curve' effect** – Refers to potential cost reduction on the basis of experiences and reduction of errors
    - High product volume is an enabler of the 'learning curve' effect
    - Built up of the 'learning curve' effect at the vendor and/or module fabricator with the M&S business model that results in increased productivity and efficiency which can reduced schedule.
    - Built up of the 'learning curve' effect for the subcontractor that executes construction for the M&S business model. This can result in increased productivity and efficiency which can result in reduced schedule.
    - Built up of the 'learning curve' effect at the vendor and/or module fabricator with the M&S business model that results in increased productivity and efficiency and can result in reduced schedule.
- **Parallel manufacturing** – Refers to the potential to manufacture some items in parallel with each other
    - An enabler of parallel engineering is modularity. Without a modular design (i.e. stick-built) it is unviable to manufacture in parallel
    - A benefit of parallel manufacturing is a reduced schedule plants from the M&S business model
- **Using a Fabrication yard** – Refers to the fact that the plant is built 'partially' in a closed and controlled environment.
    - An enabler of using a fabrication yard is modularity.
    - A benefit of using a fabrication yard is reduces safety risk
    - A benefit of using a fabrication yard is reduced schedule risk
- **Owning a fabrication yard**
    - Potential to store an inventory at the fabrication yard resulting in shorter lead-times and less contingency costs
- **Company commitment –** Refers to a situation in which all the employees agree on the use of a certain business model/vision
    - A barrier can exist when the condition 'company commitment' does not hold. This barrier is the 'Resistance to change' that exists among personnel.

These are the conditions from a Clients perspective.

- **Investment costs** - Capital expenditures required by the client to acquire a plant
    - Costs of an M&S plant can be reduced for subsequent M&S plants due to the 'learning curve' effect
    - Costs of an M&S plant can be reduced when procurement discounts apply for the M&S business model
    - Costs of an M&S plant go down when best practices for operator training (i.e. operator training programs) are offered to the client.
- **Schedule**
    - The increased productivity and efficiency from the 'learning curve' effect will result in a reduced schedule for the M&S business model

  - The possibility to manufacture in parallel will result in a reduces schedule for the M&S business model
- Risk
  - The potential to use a fabrication yard for the M&S business model will reduce the schedule risk
  - Schedule risk will also go down for the M&S business model when the plant engineer own a fabrication yard.
  - Due to the experience gained in previous M&S plants the operational risk for other M&S plants will go down

Sub-RQ 5: *What conditions that play a role in the M&S/'traditional' business model trade-off can be found when doing a Case study at Technip?*

The full *Reflected 'list of conditions'* can be found in Chapter 6. A summary of this 'list of conditions' combined with a brief argumentation is given below. First the conditions from a plant engineering perspective will be introduced then the conditions from a clients perspective.

- Modularity – Refers to the condition where modular design is used in the business model. A modular design means that the design is ‘split-up’ in modules.
  - There are extra costs for the M&S business model because the modular design should be developed for the most severe conditions/scenarios.
  - Modularity in an M&S plant required much thinking and brainstorming between the different disciplines, this is an extra cost of the M&S business model
- Using a Fabrication yard – Refers to the fact that the plant is built ‘partially’ in a closed and controlled environment.
  - When there can be built in a fabrication yard this enables the benefits of ‘location factors’
  - Location factors enable the ‘manipulation’ of the construction costs. When the fabrication yard is chosen in an area with cheap labor relative to the on-site location that is relatively a more expensive area of labor.
  - Local labor regulation from in country in which the plant is built can block the ‘location factor’ benefits
- Procurement discounts - Refers to the potential of obtaining discounts on materials from the supply side?
  - Some clients have their own preferences of vendors and subcontractors to be used (pre-qualified lists) which acts as blocker for the plant engineer to develop frame agreements.
- ‘Learning curve’ effect – Refers to potential cost reduction on the basis of experiences and reduction of errors
  - Some clients have their own preferences of vendors and subcontractors to be used (pre-qualified lists) which blocks the built-up of the ‘learning curve’ effect at a particular vendor or subcontractor.
- Standardization - The condition ‘standardization’ refers to the degree of repeatability that can be reached for a plant.
  - A cost of the M&S business model are the design cost for the first M&S plant, this is higher than a similar traditional plant. This was made explicit with the in depth case study

- A benefit of the M&S business model is the substantial lower design cost for every n^{th} (subsequent) M&S plant in relation to a similar 'traditional' plant. This was made explicit in the in depth case study.

- Design variations - The condition 'Design variations' refers to the requirement to alter a design as per client wishes.
  - Costs of the M&S business model are potential design variations. Sometimes a design variation is absolutely necessary to fit the plant on the location.
- Technological improvements - The condition 'Technological improvements' refers to the requirement to improve the existing plant design.
  - A potential cost of the M&S business model might be requiring technological improvements or design updates.
- Market segment fit - The condition 'Market segment fit' is a condition that refers to the extent to which the incumbent plant engineer's current market segment fits with a potential other market segment
  - A cost of the M&S business model might be the lack of a good market segment fit. Time, effort and costs are required when the M&S plants are sold in a different market segment.
- Plant capacity - The condition 'Plant capacity' means to the size, or the throughput, of a plant.
  - A low plant capacity enables the success of the M&S business model. Namely, for lower plant capacities the CAPEX becomes more important than the OPEX.
  - The current market segment in which the incumbent plant engineer operates (e.g. high plant capacities) can also block the adoption of the M&S business model.
- Module size - The condition 'Module size' refers to the size of the modules which can be used in the M&S design.
  - The module size is correlated to the risk. All module larger than container size have increased transportation risk (damaging of modules and late delivery)
  - All modules larger than container size have increase cost of transportation
- Modular transferability - The condition 'Modular transferability' refers to the potential to use existing individual modules in the 'new' M&S design, or to the potential to use individual M&S modules in other future designs
  - In the case that an existing individual module can be used for the 'new' M&S design front-end costs will be saved for the design and development of the M&S plant. Thus, this beneficial for the M&S business model.
  - In the case that an individual module from the M&S plant can be used for a future plant design this will save front-end costs for that future plant in particular. Thus, this beneficial for the M&S business model.

Summary of the conditions with a client's perspective.

- Investment costs - Capital expenditures required by the client to acquire a plant
  - When an M&S plant is an exact 'repeat job' this case save substantial home office engineering costs and thus lower investment costs.
  - When a beneficial location for the fabrication yard can be used to build an M&S plant this can save construction costs and thus investment costs for the client.
- Energy efficiency – The efficiency of operating an M&S plant relative to a 'traditional' plant
  - The inability to 'tweak' an M&S plant to site conditions results in a lower energy efficiency of the M&S plant in relation to the traditional plant

- The lower the plant capacity, the smaller the plant, the less relevant it becomes that the energy efficiency of an M&S plant is lower. Namely, this is due to the fact that the share of the investment costs becomes more important.

Sub-RQ 6: *How can an assessment framework be developed that takes into account all the researched conditions and that can help the incumbent plant engineers in evaluating whether the M&S business model is good option?*

The assessment framework was develop as a questionnaire in which the conditions from Chapter 4 and 6 are translated into a set of questions. The full assessment questionnaire can be found in Table 10 and 11 (Chapter 7). The assessment questionnaire is subdivided into ***factual*** and ***perceptual*** questions. The *factual* questions have a higher weight since they are based on descriptive information and therefore provide 'hard' evidence. The *perceptual* questions have a lower weight since they are based on normative information and provide the 'perception' and 'gut feeling' of the respondent. The *perceptual* questions are only relevant when the *factual* questionnaire gives an unsatisfactory outcome (e.g. a 'tie'). Both the factual as well as the *perceptual* questionnaire come forth from the all the conditions treated in Chapters 4 and 6. The conditions are translated to questions as seen in Appendix F and G. Since this assessment questionnaire is based only on initial information and is not yet validated it should be seen as a 'first cut' or 'stepping stone' towards a better assessment framework. For this reason, the author likes to describe this assessment questionnaire as a 'pre-assessment' framework; Namely, it can be used as 'quick scan' to identify whether the 'traditional' business model is still required or that more effort should be put into evaluating the M&S business model.

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Appendix A. Interview summary Director estimating

Table 3 introduces all the interviewees that were selected for interviews as data collection during the Case study. Since the interview were held in Dutch, the summary is also in Dutch.

Inleiding

- Ze zijn bezig met een modulair en standard ontwerp ook hier bij Technip
- Als cost estimators zijn wij bezig om een schatting van de kosten op te zetten voor zo een modulair en standaard fabriek

Verschillen tussen de business modellen

- Je hebt bepaalde voordelen voor het modulair bouwen door de plek waar de fabrication yard staat. Deze voordelen spelen dan natuurlijk ook op als je een modulair en standaard plant gaat bouwen. Je hebt te maken met de kosten van arbeid op een bepaalde plek en een bepaald aantal standaard uren. Als de fabrication yard voordelig kan worden gekozen t.o.v. de site locatie kan het kosten besparen.
- Voor onze huidige klanten is flexibiliteit erg belangrijk. Deze flexibiliteit komt vaak voort uit de voorkeur van klanten om liever meer te investeren in een efficiënte plant zodat ze dit later terugwinnen in de operationele kosten. Als de klant voor een M&S fabriek gaat word deze flexibiliteit ingeruild voor een lagere kapitaal investering maar hebben ze dus minder inspraak.
- Omdat je dus het standaard element in de plant hebt zal het waarschijnlijk betekenen dat je veel minden engineering kosten gaat krijgen. Het is wel belangrijk dat het eerste ontwerp echt 'goed' is en dat er in de toekomst dus geen veranderingen meer mogen worden aangebracht anders gaan de kosten weer omhoog. Je moet het er dus voornamelijk van hebben dat je home office uren flink omlaag gaan
- Wat je ook in gedachte moet nemen zijn de kosten van marktonderzoek en nieuwe markten intreden. Als je een modulair en standaard ontwerp gaat gebruiken dan gelden de oudere referenties van EPC aannemers waarschijnlijk niet meer. Je moet potentieel nieuwe klanten aanspreken en dit zijn allemaal extra kosten voor het M&S model. Het opzetten van schalies teams kan natuurlijk ook een grote kostenpost zijn. Alleen al de mensen aannemen die de contacten hebben in de juiste industrie voor het M&S model is een dure kostenpost.
- Technologische vooruitgang is een potentiële kostenpost voor het M&S model. Als er een vooruitgang komt in de technologie dan kunnen er grote wijzigingen komen in het ontwerp van het model. Dit zorgt ervoor dat de financiële haalbaarheid van een M&S model erg omlaag gaat, hier moet dus rekening mee worden gehouden.
- Een andere barrière waar rekening mee dient te worden gehouden is de verandering in de manier van denken binnen het bedrijf. Deze verandering is altijd een lastig element omdat sommige mensen al heel veel jaren dezelfde taken uitvoeren. Een verandering van business model betekent dus ook dat er eventueel een verandering van de bedrijfscultuur kan vinden. Het veranderen van de bedrijfscultuur is vaak de grootste barrière.

- Je hebt als EPC aannemer ook waarschijnlijk een lager risicoprofiel voor een M&S plant. Dit zie je voornamelijk terug in vergrote duidelijk tijdens de engineering fase, er zijn gewoon minder onvoorziene situaties. Natuurlijk is het werk in een fabrication shop veel veiliger in vergelijking tot op de site werken.
- De klant kan je een lager risicoprofiel aanbieden met een M&S plant. Je hebt een kleiner 'Schedule' risico omdat je dus in een shop werkt. De klant heeft waarschijnlijk tijdens de operatie fase ook minder veiligheid risico omdat een M&S plant een standaard ontwerp waar al ervaringen mee zijn opgedaan.

Appendix B. Interview summary Project Manager 1

Table 3 introduces all the interviewees that were selected for interviews as data collection during the Case study. Since the interview were held in Dutch, the summary is also in Dutch.

Inleiding

- Er zijn twee gedachten stromen in jou scriptie (1) wat de meeste EPC aannemers nu doen en de (2) M&S manier. Ik begrijp ook dat je een model wil opstellen waar je de financiële en non-financiële vergelijk maakt tussen de twee modellen.
- Wij doen zelf wel eens een project modulair maar ook niet vaak. Het idee om standaard te gaan is best nieuw voor dit kantoor, ze hebben er in ieder geval al wat werk aan verricht. Van modulair weer ik dus best wel wat maar van standaard iets minder.

Verschillen tussen de business modellen

- Team committent – Wij hebben hier zelf gemerkt tijdens de ontwikkeling van onze M&S waterstof fabriek dat er een goede samengewerkt moet worden tussen de disciplines. Hier is het destijds in serie gegaan (eerst proces dan piping dan constructie etc.) maar het moet in parallel. Natuurlijk werkt in serie ontwerpen wel voor ons 'traditionale' manier maar dus niet voor het M&S ontwerp. Als er niet in parallel word gewerkt heb je dus een barrière en worden de kosten voor het model ontwerp vele malen duurder.
- Standaard ontwerp – Omdat je dus een standaard ontwerpt hebt ga je in de loop van de tijd zien dat je minder engineers nodig hebt voor eerstvolgende plants, ook zelfs minder purchasing mensen heb je nodig. Je hebt waarschijnlijk ook minder kosten voor de coördinatie van mensen (zoals project managers en site coördinators).
- Investeringkosten – Omdat je met een geheel nieuw concept te maken krijgt worden heb je wel hogere investeringskosten dan voor een 'traditionele' plant. Je moet dus als EPC aannemer bereid zijn je verlies deels te nemen. Een groot deel van de investeringskosten zijn afkomstig uit het feit dat er met verschillende scenario's rekening dient te worden gehouden om het M&S ontwerp zo sluitend als mogelijk te maken. Je kan namelijk te maken krijgen met gevaarlijke omstandigheden zoals aardbevingen, en sommige locaties hebben een variërende voeding kwaliteit voor de plant.
- Flexibiliteit – Ik denk dat een hele belangrijke driver voor de klant is om een traditionele plant te kopen flexibiliteit is. Omdat ze een enorm grote uitgave doen en het voor zeker 20 jaar behouden willen ze invloed. Ik denk dat deze invloed voornamelijk afkomstig is uit het feit dat we vooral raffinaderijen als klant hebben. Zij hebben vaak specifieke wensen wat betreft de condities van het product.
- Modulair ontwerp – door het modulaire ontwerp heb je waarschijnlijk wel extra kosten voor het staal om de modules te verstevigen.
- Coördinatie kosten – Je hebt waarschijnlijk de eerste keer tijdens het construeren verhoogde coördinatie kosten omdat de modules gewoon goed op elkaar aan moeten sluiten en het vaak ook de eerste keer is dan een bepaalde fabrication yard dit doet.
- Verminderde on-site kosten – Omdat je een hoop werk naar de fabrication yard kan verschuiven zal je veel minder kosten on-site hebben. De modules worden namelijk in de fabrication yard gemaakt. Je hebt gewoon een kleiner team van mensen nodig om alles te controleren.

- Transport kosten – De transport kosten zijn heel erg afhankelijk van de grootte van de modules. Het is in de regel vaak hoe groter de module hoe groter de transport kosten. Daarnaast heb je ook simpelweg meer transport routes, omdat je vanaf de vendor naar de shop moet maar dus ook weer vanaf de vendor naar de site.
- Fabrication yard – Dit is een gecontroleerde omgeving en dus minder risico's daarnaast kan je hier 24/7 werken i.p.v. on-site. Je hebt minder vertraging ook van de klant die constant aanwezig is bijvoorbeeld tijdens on-site bouwen. Als je dezelfde fabrication yard blijft gebruiken dan krijg je ook optimalisatie van het werk in deze yard en dus een hogere productiviteit. Deze hogere productiviteit kan er ook voor zorgen dat de kosten omlaag gaan. Maar het kan ook weer tegen je gaan werken als er geen continuïteit is op de yard, je moet er dus voor zorgen dat er wel klussen blijven komen anders kost zo een fabrication yard alleen maar geld.
- Locatie van de fabrication yard – Een belangrijke factor is de plaats waar de fabrication yard is. Het kan namelijk grote kosten voordelen opleveren als deze op een gunstige locatie staat waar de kosten van arbeid laag zijn en de efficiëntie hoog. De Australische outback heeft enorm hoge arbeidskosten dus als je dan in een fabrication yard ergens in Thailand kan bouwen kan je alleen hierdoor al geld besparen.
- Risico's – Het risicoprofiel voor een M&S fabriek is over het algemeen lager. Een belangrijk risico is Schedule risk deze word zeker verminder bij M&S omdat je modules parallel kan ontwikkelen en je dus door kan blijven werken in die gecontroleerde shop omgeving. Doordat je in een gecontroleerde omgeving kan bouwen betekent dit dat je minder risico op vertraging hebt. Daarnaast heb je ook minder veiligheidsrisico doordat je minder op hoogtes werkt en een minder gevaarlijke omgeving hebt. Risico's die je dus vermeid op site zijn; branden, het weer, ongevallen etc. Nog een risico is de levering van materiaal, deze is on-site groter dan voor een fabrication yard.
- Kwaliteit – De kwaliteit van een M&S plant is waarschijnlijk groter als die van een 'traditionele' plant. Dit komt omdat je meerdere keren hetzelfde werk gaat uitvoeren en dat zorgt ervoor dat je minder fouten gaat maken in je ontwerp en tijdens de constructie.
- Kosten van engineering drastisch omlaag – Omdat we met het M&S ontwerp naar een zogenaamde 'repeat order' gaan zullen de engineering kosten heel erg omlaag gaan voor de n^{de} plants die verkocht worden. Ik schat dat je kosten voor engineering misschien wel 4/5e omlaag gaan. Dit zal ook het belangrijkste voordeel van M&S zijn.
- De duur van projecten zal omlaag gaan – Met in gedachten de M&S waterstof plant zal het op de traditionele manier ongeveer 21 maanden duren voor het project af is en voor de M&S manier maar 15 maanden.
- Minder winst relatief – Omdat de schalies functie waarschijnlijk onder druk ligt om het M&S ontwerp te verkopen zullen ze voor 'minimale' winst gaan. Dit zal betekenen dat er dan relatief minder winst wordt geboekt dan voor een 'traditionele' plant. Dus de margin zal waarschijnlijk hetzelfde blijven (ongeveer 8%) maar omdat een M&S plant minder kost zal er dus relatief minder winst gemaakt worden.
- Volledige EPC bekijken – Het is belangrijk om voor je vergelijking de gehele EPC fase meet e nemen. OP deze manier kan je goed naast elkaar leggen waar de verschillen zitten. Wij als EPC aannemer hebben ook weleens alleen 'design packages' die we verkopen, maar waarschijnlijk is het meest voordelig voor M&S om een EPC contract te verkopen omdat het de voordelen van een standaard en modulair ontwerp zich niet alleen bij de engineer bevinden maar ook bij de inkoop en constructie.

Appendix C. Interview summary Vice President 2

Table 3 introduces all the interviewees that were selected for interviews as data collection during the Case study. Since the interview were held in Dutch, the summary is also in Dutch.

Inleiding

EPC aannemers werken altijd wel tot op bepaalde hoogte gestandaardiseerd, maar er is nooit echt 'repeat order' werk. Je ziet vaak simpelweg dat onze klanten een erg specifiek eisenpakket hebben, vooral raffinaderijen. Daarnaast is een standaardontwerp ook vaak een probleem omdat elk land zijn specifieke eisen heeft wat betreft veiligheid en plaatsing eisen van de plant, dit maakt het nog extra lastig om een standaard plant te leveren voor klanten omdat er dan weer allerlei variaties in het design komen die ook weer geld kosten.

Als Technip wilde wij een standaard ontwerp omdat we voor elke BDEP ongeveer 8000 home office uren kwijt waren. Dus het begon meer als een idee voor een 'basis' ontwerp die we dan konden uit bouwen tot een maatwerk plant. Wij hadden geschat dat zo een standaard BDEP zo een 3/4000 home office uren kon besparen. Dit hebben we eigenlijk besloten met een 'gut feeling'.

Verschillen tussen de business modellen

- Flexibiliteit – een belangrijke drijfveer voor klanten om een maatwerk plant te kiezen is volgens mij de flexibiliteit in het ontwerp. Onze klanten gebruiken vaan een waterstof plant als utiliteit voor een andere plant, dit houdt in dat ze hele specifieke eisen hebben wat betreft de condities van het product en/of bijproducten. Daarnaast is de plaatsing ook vaak gebonden aan andere delen van de plant die ervoor kunnen zorgen dat standaard ook geen optie is. M&S is dus gewoon een ander business segment.
- Minder engineers M&S – Als je de vergelijk zet tussen traditioneel en M&S zijn er voor het M&S ontwerp veel minder mensen in de front end nodig. Je zult van een bureau van 200 engineers naar 40 engineers gaan.
- Contracten vastleggen met vendors – Als je het M&S model gebruikt is er de mogelijkheid dat je contracten kan vastleggen met verschillende vendors. Dit zijn dan een soort raamcontracten die ervoor zorgen dat de vendor gegarandeerd werk heeft en dat jij gegarandeerd een lagere prijs hebt.
- Home office kosten omlaag M&S– Ik denk dat de home office kosten voor het M&S model ongeveer een kwart omlaag gaan in vergelijking tot die van traditioneel.
- Risico is lager – Het risico van het project zal lager zijn voor M&S. Mede omdat je werk kan verrichten in een fabrication yard kan je verwachten dat je minder risico's krijgt tijdens constructie. Typische risico's zijn veiligheidsrisico's op site, de levering van materiaal kan vertraagd zijn als je site moeilijk bereikbaar is. Daarnaast is het in een fabrication yard veiliger omdat je in een gecontroleerde omgeving werkt.
- Minder tijd nodig voor constructie – je kan in een fabrication yard langer doorwerken omdat je niet geremd word door weersomstandigheden.
- M&S minder efficiënt – je M&S plant zal relatief minder efficiënt worden dan een maatwerk plant. Je kan namelijk niet de plant optimaliseren voor de klant en zijn aangeven omgevingscondities.

- Capaciteit van de plant – De capaciteit van een plant is naar mijn mening een belangrijk factor. Je ziet namelijk dat hoe groter een plant is hoe belangrijk de operationele kosten relatief worden. En hoe kleiner de plant hoe belangrijker de investeringskosten worden. Je ziet dus weer dat een M&S model vooral een ander marktsegment is waar dat interessant is (kleinere plants). Je ziet soms bedrijven die kleinere plants inderdaad standaard verkopen omdat de markt er daar wel voor is, voor grote 'traditionele' plants zie je dit veel minder.
- Locatie van de plant of fabrication yard – De locatie is ook belangrijk om over na te denken. Je ziet dat de locatie van een plant in sommige gevallen gebruikt word om een modulair ontwerp toe te passen omdat de kosten om on-site te bouwen erg hoog kunnen zijn. Het bouwen in fabrication yard kan dan voordelig zijn omdat de kosten van arbeid daar lager zijn.
- Onderhoud voordelen – Ik zie dat sommige bedrijven DOW en Air Products al hun plants standaardiseren. Als dit gebeurt zie je dat er dan wel degelijk voordelen ontstaan omdat de klanten bijna verplicht worden hun onderhoud bij deze bedrijven te houden. Dit is voor de klant voordelig omdat ze deze onderhoud tegen relatief lage prijzen kunnen aanbieden. Voor de EPC aannemer is dit voordelig omdat ze zo hogere kwaliteit van hun apparaten kunnen garanderen en door onderhoudscontracten verdien ze weer geld.

Appendix D. Interview summary Project Manager 2

Table 3 introduces all the interviewees that were selected for interviews as data collection during the Case study. Since the interview were held in Dutch, the summary is also in Dutch.

Inleiding

- Op dit moment is dit kantoor voornamelijk bezig met het leveren van maatwerk, hier zijn wij ook in gespecialiseerd. We werken zo nu en dan wel modulair maar dit is nog steeds voor elk project volledig maatwerk. Wat ik er nu over denk ik dat je voor het M&S model een flinke investering nodig hebt omdat je een ontwerp gaat maken voor one-size-fits all. Dus zoals ik het nu zie is M&S voor ons als Technip een flinke investering waar de vooruitzichten erg onduidelijk voor zijn.

Verschillen tussen de business modellen

- Multi disciplinaire teams nodig – Een grote barrière kan zijn dat je voor je M&S ontwerp niet goed samenwerkt met de verschillende disciplines. Dit kantoor is op dit moment bezig met een M&S ontwerp maar we hebben wel gemerkt dat het verre van vlekkeloos is verlopen. Voor een maatwerk fabriek weer iedereen wat hij moet doen, alle disciplines kunnen los van elkaar aan de slag en communiceren toch goed met elkaar. Voor een M&S plant werkt dit totaal niet, het goede aflopen van de M&S plant valt en staat naar onze mening met constante interactie tussen de verschillende disciplines.
- Afname in personeel – Ik weet bijna zeker dat als dit kantoor volledig voor het M&S ontwerp zou gaan er veel mensen niet meer nodig zullen zijn. Dit komt voornamelijk door het standaard element van het M&S model, dit zorgt er namelijk voor dat je het ontwerp bijna ‘van de plank’ kan halen en er dus minder design kosten nodig zijn. Daarnaast zullen er ook minder inkopers en constructie personeel nodig zijn omdat er met vaste procedures en leveranciers gewerkt kan worden. Over het algemeen zullen de kantoor uren (ongeveer 30% van de verkoop) met minstens meer dan de helft afnemen.
- Initiële kosten modulair ontwerp hoger – De initiële kosten voor het ontwerp van een modulaire plant, zoals in het M&S model, zullen hoger zijn. Je hebt namelijk altijd meer coördinatie nodig tijdens het ontwikkelen van modulaire plants. Deze coördinatie is nodig omdat dus naast een sluitend procesontwerp de modules ook perfect moeten aansluiten dit vereist dus een constante communicatie tussen verschillende disciplines. Deze coördinatie kosten zullen echter wel minder worden als er meerdere M&S project zijn uitgevoerd.
- Blijvende kosten modulair ontwerp hoger - Je hebt voor een modulair ontwerp ook altijd meer kosten voor structureel staal omdat de modules verstevigd moeten worden. Dit extra staal is altijd nodig. Je hebt voor de meeste modulaire ontwerpen ook verhoogde transformatie kosten in vergelijking tot een maatwerk plant. Dit is omdat een module vaak een groot en log voorwerp is die speciale transportmiddel nodig heeft om naar de plek van bestemming te komen. Daarnaast zie je vaak dat er dubbel transport nodig is om het materiaal naar een werkplaats te krijgen en daarna weer naar de site.

- Je krijgt een 'nieuwe' fase 'Assembly' – Deze nieuwe fase komt erbij voor het M&S model. Dit betekent simpelweg dat het materiaal van de vendor in een fabricatie shop tot modules word gebouwd, dit is dan de assemblage van de modules. Deze assemblage fase heeft veel voordelen t.o.v. enkel een constructie fase voor een maatwerk plant. Je ziet namelijk dat het werk tijdens een assemblage fase (bv. een overdekte werkplek) veel veiliger is, er zijn minder veiligheid risico's doordat er minder op hoogtes gewerkt hoeft te worden en je hebt een schone en gecontroleerde omgeving. In tegenstelling tot de constructie fase die alleen op de site plaatsvindt waar je afhankelijk ben van het weer en waar er naar ervaring meer ongelukken gebeuren dan in een werkplaats. Mede omdat je bij het M&S model minder op site werkt heb je dus ook minder 'site establishment' kosten zoals huizing of kranen en dergelijke.
- Voordelen werkplek- Het kan een voordeel zijn dat je modules kan bouwen in een werkplek. De module werkplek hoeft namelijk niet speciaal in het land te worden gebouwd waar de plant wordt gebouwd. Het land waar de plant word gebouwd kan dure arbeid hebben en als je dus een werkplek in een land met goedkoper arbeid kiest levert dit voordeel op. Echter, een nadeel kan zijn dat er in bepaalde landen wetten zijn die aangeven dat er een verplicht aantal procent werknemers uit het land moeten komen waar het project wordt gebouwd. Dit zou betekenen dat dit voordeel niet meer op gaat.
- Afname van de miscellaneous kosten – Deze kosten worden altijd door een EPC aannemer toegevoegd door de onzekerheid in projecten. Voor maatwerk projecten is die onzekerheid relatief groot maar voor een M&S plant kan die in de loopt van de tijd aanzienlijk afnemen. Dit komt omdat je meer zekerheid hebt over de productie van de plants, het word een 'repeat' job. Als je het al een paar keer hebt gedaan kan je best practices ontwikkelen en die zorgen ervoor dat je operatie bijna vlekkeloos kan verlopen.
- Parallel modules ontwikkelen – In tegenstelling tot een maatwerk plant hoef je niet te wachten tot een bepaalde unit gebouwd is. Voor een maatwerk plant is dit nodig omdat er een bepaalde afhankelijkheid kan bestaan tussen de lay-out van de plant, sommige apparaten worden zo gebouwd dat het onmogelijk word om deze te monteren of demonteren zonder dat er dan andere apparaten moeten worden weggehaald. Voor een M&S ontwerp heb je deze lastigheid niet. Je kan dus als je zou willen alle modules tegelijk fabriceren zonder dat er een 'wachttijd' is. Dit is dus iets wat ook je 'Schedule' time drastisch gaat verkorten. Naast dat het parallel ontwikkelen de Schedule tijd verlaagd heb je hierdoor dus ook minder risico dat je het Schedule niet haalt. Dit omdat er dus geen afhankelijkheden (wachttijden) meer bestaan tussen de units.
- Kwaliteit van de M&S plant word hoger – De EPC aannemer, en in sommige gevallen de vendors en subcontractors (in het geval je dezelfde partijen kiest), worden meer ervaren in het ontwikkelen van een standaard product. Elke keer dat een M&S plant wordt ontwikkeld word er geleerd van de fouten, dit zorgt ervoor dat in de ontwikkeling van de volgende plant minder fouten worden gemaakt end e kwaliteit van het product dus omhoog gaat.
- In het generaal lager risicoprofiel voor M&S – Je kan er vanuit gaan dat er voor een M&S plant in het algemeen minder risico's gelden dan voor een maatwerk plant. Een deel van deze risico's is afkomstig uit het feit dat je bij een maatwerk plant op site werkt. Op site heb je altijd te maken met persoonlijke veiligheid risico's (werken op hoogtes, werken met hoge drukken en temperaturen zonder goede bescherming). Daarnaast heb je op site ook meer 'Schedule' risico (afhankelijkheid in constructie volgorde, weersomstandigheden, niet 24/7 kunnen werken). Ook is er soms het arbeid risico, dit houdt in dat er op sommige sites heel lastig is om arbeid te vinden, voor het M&S model is dit risico er niet.

- Variaties in het design – Proces technisch kan M&S nog wel een probleem vormen. Dit komt omdat de ervaring leert dat omstandigheden om alle locaties in de wereld zo verschillend kunnen zijn. Als ik kijk naar onze waterstof plants die hebben heel vaak bijvoorbeeld al andere voedingscondities of temperatuurcondities waar het design voor aangepast moet worden. Of denk bijvoorbeeld aan bepaalde bijproducten die je wel of niet kan produceren. Je zou dan dus extern weer modules aan moeten bieden om deze condities het hoofd te bieden.
- Verlies van efficiency – Omdat je dus een standaard ontwerp maakt kan deze dus niet worden aangepast voor specifieke condities van een klant. Een klein verschil in voedingscondities en/or temperatuur condities kan al minder efficiëntie opleveren. Dit betekent dat een plant minder efficiënt zal draaien. Ook dit is vaak een reden dat onze klanten zoveel maatwerk willen. Met maatwerk word de plant volledig geoptimaliseerd. Dit betekent wel hogere investeringskosten maar in de loop van de tijd kunnen ze dit eruit halen met de productie kosten.

Appendix E. Interview summary Vice President 1

Table 3 introduces all the interviewees that were selected for interviews as data collection during the Case study. Since the interview were held in Dutch, the summary is also in Dutch.

Inleiding

Zoals ik het zie is dat we met ons maatwerk model volledig kijken wat de klant wil en al zijn eisen erin verwerken. We 'designen' en 'engineeren' hem dus precies zoals de klant wilt. Wat ze willen varieert van volledige inspraak in het design tot kleine aanpassingen. Voor het modulaire en standaard model veranderd dit natuurlijk volledig, de klant krijgt dan zo goed als geen inspraak meer. Met ons maatwerk model zie je vaak dat we een voordeel voor de klant kunnen aanbieden op basis van ‘overall energie consumptie’ (en lagere OPEX in het algemeen) en we proberen natuurlijk een lagere CAPEX dan de klant aan te bieden, maar de markt voor waterstof is behoorlijk competitief.

Een grote drijfveer voor ons om voor de waterstof plants over standaardisatie na te denken was voornamelijk dat we voor kleinere plants erg duur weren als investering voor de klant. Daarnaast moeten we natuurlijk constant de klant voorop stellen en de klant kunnen overtuigen van het voordeel.

Verschillen tussen de business modellen

- De klant overtuigen/nieuwe klanten vinden – Het is van groot belang dat we de klant weten te overtuigen van het voordeel van een M&S plant. Als EPC aannemer ben je nou eenmaal geneigd om te doen wat de klant wilt, je bouwt simpelweg een plant naar zijn eisen. Als een EPC aannemer die altijd maatwerk heeft verkocht gaat wisselen naar het verkopen van standaard plants zullen er hoogstwaarschijnlijk andere klanten moeten worden gevonden. Dit zijn dus extra investeringskosten voor het M&S model omdat er een nieuwe markt dient te worden gevonden. Klanten die geïnteresseerd zijn in maatwerk zijn vaak grote spelers die de efficiëntie van de fabriek verkiezen boven de investeringskosten. Je gaat waarschijnlijk dus zien dat met een M&S plant kleinere plants veel aantrekkelijker worden voor de klant i.p.v. een maatwerk plant. Dit omdat de relevantie van investeringskosten t.o.v. operationele kosten groter word voor kleinere plants. Maar het kan dus gezien worden als een barrière voor de EPC aannemer met het maatwerk model om te switchen naar het M&S model, omdat het zoeken van nieuwe markten dus geld kost
- Kosten reductie – Als een EPC aannemer alleen het M&S model gebruikt voor zijn business worden de kosten waarschijnlijk flink gereduceerd. Je gaat namelijk zien dat de initiële inspanning voor de ontwikkeling van een M&S plant vrij intensief is maar de n^{de} orders zullen veel minder inspanning nodig hebben vanaf het kantoor. Dit is met name omdat de engineers ervaring krijgen met het ontwikkelen van de standaard plant (learning curve) en omdat er hele stuk werk kunnen worden overgeslagen doordat het een standaard ontwerp is. Dus vooral discipline engineering gaat voor een M&S plant drastisch omlaag.

- Psychologische barrière – Op het kantoor hier bij Technip werken mensen al heel hun leven werken aan het maatwerk principe. Als je als EPC aannemer dan een drastische switch gaat maken naar een ander business model ga je met zekerheid weerstand krijgen bij verandering. Dit is een belangrijke barrière die je ondervind bij een verandering. Het gaat tijd, en dus geld, kosten om de werknemers en het management voldoende mee te krijgen in het concept. Het kan ook zo zijn dat je werknemers gaat krijgen die minder gemotiveerd zijn omdat het werk minder uitdagend zal zijn als je met standaard producten werkt.
- Standaard overeenkomsten met leveranciers – Een belangrijk element voor de kosten van het M&S model zijn de potentiële raamcontracten die je kunt opzetten met leveranciers. Als je een standaard product maakt (M&S plant) dan bestaat er de mogelijkheid om een leverancier te zoeken die geïnteresseerd is om tegen gereduceerd tarief materialen aan te bieden, dit in ruil voor de zekerheid dat er altijd bij deze leveranciers wordt afgenomen. Aangezien de kosten van materialen vaak procentueel de hoogste zijn van de EPC van een plant kunnen hier grote voordelen op worden gehaald.
- Doorzet van een productie plant – In ons geval proberen we om onze ‘kleine’ waterstof plants te standaardiseren. Dit omdat de capaciteit vaak een belangrijke doorslag kan geven in het belang van de investeringskosten ten opzichten van de operationele kosten. Bij grote plants loont het vaak de moeite om extra veel geld in the engineering te stoppen, dit kan er namelijk voor zorgen dat de efficiëntie omhoog gaat. En dit aandeel van de efficiëntie is groter dan het aandeel van de aanschafkosten.
- Barrière voor raamcontracten – Iets waar wel rekening mee dient te worden gehouden zijn de eisen van potentiële klanten voor ‘per gekwalificeerde’ leveranciers of onderaannemers. Dit kan een barrière zijn die ervoor zorgt dat een standaard overeenkomst met een leveranciers helemaal geen nut heeft.
- Kosten van de eerste M&S plant – Je moet er van uit gaan dat de EPC kosten van de eerste M&S plant als een soort van investering kosten kunnen worden gezien. Je moet er rekening mee houden dat er een plant wordt gemaakt die voor een groot scala aan klanten een goede ‘fit’ moet hebben. Daarnaast zullen de modules ook goed doordacht moeten worden zodat ze niet meer veranderd te hoeven worden voor toekomstige klanten. Dus coördinatie kosten worden zeker groter de eerste keer. Ook moet je rekening houden dat het design extra stevig moet worden uitgerust zodat het tegen alle omstandigheden bestand is (bijvoorbeeld aardbevingen). Als je hier dan rekening mee houdt zorgt dit ervoor dat je in de toekomst geen wijzigingen meer in het ontwerp hoeft aan te brengen.
- Grootte van de modules – De grootte van de modules is een belangrijk element. Hoe groter the module hoe lastiger bijvoorbeeld het transport gaat worden. Het risico van transport is dus groter voor grote modules. Denk hierbij dan aan tijd risico (vertraging) en de mogelijke beschadiging die het kan oplopen tijdens transport. Als modules bijvoorbeeld klein zoals containers kunnen zijn worden deze risico’s al fors verminderd. De kosten voor het transport van grote modules is ook veel duurder dan als je modules hebt van container grootte.
- Voordeel voor de klant – Zoals al uitgelegd zal de klant flexibiliteit inleveren van het maatwerk. Maar daarvoor terug krijgt hij een lagere investeringskosten voor de plant die sneller op de markt gebracht kan worden. De kosten van de plant zijn dus voornamelijk lager omdat de kosten bij de EPC aannemer worden gedrukt in een standaard ontwerp. De ervaring in het maken van een M&S plant en het gebruik van een werkplaats zorgt ervoor dat de plant in minder tijd kan worden gebouwd.

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Appendix F. 'Transforming' conditions to factual questions

This Appendix is devoted to an elaboration on the 'transformation' process condition from Chapter 5 and 7 to factual questions. This appendix will review the *factual questions* and a small section follows that elaborates on the reasoning behind the question and what answer is positive for the success of the M&S business model.

Question 1 *The number of M&S plants that could potentially be sold is ? (answer with best knowledge of current market and plant engineers situation)*

- A very important, if not the most important, question that is asked. This is the only question that is not transformed from any of the conditions. However, it was deemed important because the number plants sold is the biggest indicator of success. This question forces the respondent to think about potential clients and customers which would be willing to buy an M&S plant.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 4-6 or higher

Question 2 *How much experience does the company have with modularity? (has it been done before?)*

- This question is based on condition 1 from Chapter 5; modularity. Even though modularization can be a costly endeavor for plant engineers it is seen as a major enabler of standardization. Furthermore, these ' extra' costs will diminish when more plant are produced. Thus, when a company is experienced in modular designs, this will be extra beneficial for the plant engineers that wishes to introduce the M&S business model.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question 'Much' or 'Very much'

Question 3 *How much experience does the company have with M&S? (has it been done before?)*

- This question is based on condition 1 from Chapter 7; Standardization. Standardization is mostly already applied in the plant engineering industry, however, this type of standardization is on a very low level (e.g. valves, piping etc.). There is often no real experience with standardization on full plant level. In case there is experience with this 'high level' standardization it is deemed to be a positive thing for the M&S business model
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question 'Much' or 'Very much'

Question 4 *What percentage of the M&S plant can be procured by making use of current/existing frame agreements/contracts with vendors?*

- This question is based on condition 2 from Chapter 5; Procurement discounts. As explained in this condition, the potential to make use of procurement discounts can save major costs in contract with vendors. Logically, not all vendor contracts can be used. However, the respondent is asked to give an educated estimate on the potential to use these contracts specifically for the M&S plant under consideration.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question 75% or more.

Question 5 *Which percentage of the M&S plant can be constructed by making use of current/existing frame agreements/contracts with subcontractors?*

- This question is based on condition 2 from Chapter 5; Procurement discounts. Same as question 4 but this time for subcontractors.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question 75% or more.

Question 6 *What percentage of modularization will be applied for the M&S plant?*

- This question is based on condition 1 from Chapter 5; modularity. Using a modular design increases the effectiveness of standardization. For this reason, the higher the degree of modularization used in the M&S plant the more likely it is that the M&S business model will be successful.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question 75% or more.

Question 7 *How often do you encounter clients that impose you to select from 'pre-qualified' vendor and/or subcontractor'?*

- This question is based on the reflected conditions 3 and 4 from Chapter 7; Procurement discounts and 'Learning curve' effect. From the information in these conditions it became clear that some clients could block the benefits of procurement discounts and the 'learning curve' effect. Namely, by forcing the plant engineer to select a vendor/subcontractor from a 'pre-qualified' list, this will block the opportunity for the plant engineer to select his own - frame contracted - vendors/subcontractors. This will directly result in less procurement discounts and indirectly result in less 'learning curve' built up.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 'Seldom' or 'Never'.

Question 8 *What part of the M&S do you expect to built in a fabrication yard?*

- This question is based on condition 4 and 5 from Chapter 5; Parallel manufacturing and Using a fabrication yard. From these conditions it became clear that using a fabrication yard will lower overall safety and schedule risk. Furthermore, parallel manufacturing is enabled by a modular design, and since a modular is built in a fabrication yard this means that the higher the degree of the plant that is built in a fabrication yard the more can be manufactured in parallel. A high degree of parallel manufacturing means that the M&S plant will have major time benefits in relation to the 'traditional' design.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question 75% or more.

Question 9 *The overall view of this plant engineering company and his employees on the M&S business model is?*

- This question is based on condition 7 from Chapter 5; Company commitment. This condition tells us that the degree of commitment and the current company culture can be an important indicator of the success of the introduction of a new business model. For this reason, the more optimistic the view of the employees on the M&S business model the more likely its success.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 'Neutral', 'Positive' or 'Very positive'.

Question 10 *What is the chance that a fabrication yard can be chosen with a relatively beneficial hourly rate and labor productivity for a particular M&S plant?*

- This question is based on reflection condition 2 from Chapter 7; Using a fabrication yard. From this condition it became clear that a fabrication yard can offer so called 'location factor benefits' to the plant engineer. This means that a 'beneficial' location (i.e. cheap labor, high efficiency) can be chosen in relation to the on-site location. When the chance is high that this is achievable for the M&S plants, the success of the M&S business model increases.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 50% or more

Question 11 *To what extent do countries that you operate in impose regulations with regard to labor quotas in that particular country?*

- This question is based on reflection condition 2 from Chapter 7; Using a fabrication yard. From this condition it became apparent that a nuance had to be added to the potential of the 'location factor' benefits. Namely, certain countries in which plant engineers are active demand that a certain percentage of the total labor is performed in their country (i.e. invested in their economy). In this case the potential for the plant engineer to choose a particular 'beneficial' fabrication - maybe in another country - can become problematic.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 'Small' or 'Very small'

Question 12 *What percentage of standardization will be applied for the M&S plant design?*

- This question is based on condition 1 from Chapter 7; Standardization. This question is also indirectly related to condition 2 and 3 from Chapter 5; Procurements discounts and 'learning curve' effect. This question is very relevant since a large part of the benefits of M&S is expected to come from the potential to reuse the modules/parts in subsequent M&S plants. For this reason, it is imperative that a high degree of standardization will be applied. Furthermore, the less standardized elements the less potential there will be to make use of procurement discounts and the less 'learning curve' built up there will be.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 100%

Question 13 *What percentage of the M&S plant will be open for (small) design variations as per client wishes?*

- This question is based on condition 2 from Chapter 7; Design variation. As explained in this condition, design variation are a costly endeavor for a standardized plant. For this reason, the more design variation are allowed the less potential there is for the success of the M&S business model.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 25% or less

Question 14 *How often are technological improvements or 'design updates' required for the main technology in the M&S plant?*

- This question is based on condition 4 from Chapter 7; Technological improvements and updating. Just like design variation, technological improvements or 'design updates' are a costly endeavor for an M&S plant. Some technologies are more mature which means less updates required, other technologies are relatively 'new' and require more updates and continuous improvements. For this reason, the more technological improvement are expected the less potential there is for the success of the M&S business model.

- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 25% or less

Question 15 *What will be the relative plant capacity (throughput) of the M&S plant design? (relative to plants with the same technology)*

- This question is based on condition 5 from Chapter 7; plant capacity. This condition showed that the relative capacity of a plant can make a big difference for its viability for the clients. To summarize, the smaller the capacity of the plant the more beneficial it is for the client and thus the more potential to sell an M&S plant.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 'Average', 'Small' or 'Very small'

Question 16 *To what extent is the current customer/market segment (for 'traditional' plants) similar to the segment used for an M&S plant?*

- This question is based on condition 4 from Chapter 7; Market segment fit. From this condition it became apparent that, even though the same technology is used, an M&S plant might have a different market segment than a 'traditional' plant. For this reason, the respondent is asked to give an indication of how the 'fit' for an M&S plant is different than for a 'traditional' plant. Logically, the better the fit the higher the chance that M&S will be a success.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 'Normal', 'Large' or 'Very large'

Question 17 *What will be the average size of modules in the M&S plant design? (where very small is container size and very large is a full 'small' plant as one module)*

- This question is based on condition 6 from Chapter 7; module size. This question requires the respondent to select an answer on how large the modules will be in their M&S design. The smaller the modules that can be used are, the greater the chance of success for the M&S business model.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 'Small' or 'Very small'

Question 18 *To what extent can individual modules from an existing ('old') design be used in the 'new' M&S plant design?*

- This question is based on condition 7 from Chapter 7; Modular transferability. As fully explained in this condition, the potential to reuse existing individual modules from a previous (modular and standard) design can increase the success of the M&S business model.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 'Normal', 'Large' or 'Very large'

Question 19 *To what extent can the individual modules from the 'new' M&S plant be applied in the design of another modular plant?*

- This question is based on condition 7 from Chapter 7; Modular transferability. As fully explained in this condition, the potential to use some individual modules from the M&S design under consideration can increase the success of the M&S business model.
- ***'Initial weighting classification'*** -> A positive answer for the M&S business model on this question is 'Normal', 'Large' or 'Very large'

Appendix G. 'Transforming' conditions to perceptual statements

This Appendix is devoted to an elaboration on the 'transformation' process in which the conditions from chapter 5 and 7 are transformed/converted to perceptual statements. This appendix will review the perceptual statements and a small paragraph follows that elaborates on the reasoning behind the statement and for what answer the outcome can be deemed positive for the M&S business model. Logically, the factual questions have a higher validity regarding the choice between the 'traditional' and the M&S business model. However, in case of a 'tie' in the factual questions, a conclusion can be drawn from the perceptual statements (filled in by plant engineering experts). Namely, the assumption is that, even though they are 'perceptions, they are substantiated by 'plant engineering experts', that have much experience in this industry. For this reason, conclusions can be drawn from the perceptual statements.

The statements are stated in such a way that, when respondents agree, this is a positive outcome for the M&S business model.

Statement 1 *We would probably sell more M&S plants then we sell 'traditional' plants.*

- Just like the first factual question (question 1), this first statement is brought forth to 'gauge' the overall knowledge and opinion on the potential of selling M&S plants.

Statement 2 *It will be relatively easy to maximize modularization for the M&S plant.*

- This statement is based on condition 1 from Chapter 5; Modularity. As explained in this condition, modularity enables the benefits of standardization. For this reason, when it is perceived by the employees that a high degree modularization is achievable, more benefits of standardization can be obtained.

Statement 3 *I think that setting up frame contracts with vendors for the M&S plant will not be a problem in the future.*

- This statement is based on condition 2 from Chapter 5; Procurement discounts. If the general perception within the plant engineering company is positive regarding the development and use of frame contracts with vendors then the M&S business model will have a higher chance of success.

Statement 4 *I think that setting up frame contracts with subcontractors for the M&S plant will not be a problem in the future.*

- This statement is based on condition 2 from Chapter 5; Procurement discounts. If the general perception within the plant engineering company is positive regarding the development and use of frame contracts with subcontractors then the M&S business model will have a higher chance of success.

Statement 5 *We would be able to often use the same vendor for the procurement of the M&S plant.*

- This statement is based on condition 2 and 3 from Chapter 5; Procurement discounts and 'Learning curve' effect. The statement forces the respondent to choose his perception regarding the use of the same vendor. If the overall perception in the company is positive regarding the use of the same vendor for multiple M&S plants this is a positive thing for the M&S business model. Namely, using the same subcontractor will create more potential to obtain future discounts and will allows built up of the 'learning curve'.

Statement 6 *We would often be able to use the same module fabricator for the construction of the modules of the M&S plant.*

- This statement is based on condition 3 and 4from Chapter 5; 'Learning curve' effect and Parallel manufacturing. The statement forces the respondent to choose his perception regarding the use of the same module fabricator. If the overall perception in the company is positive regarding the use of the same module fabricator for multiple M&S plants this is a positive thing for the M&S business model. Namely, the same module fabricator will allow more potential to manufacture modules in parallel and it will allow a higher build up of the 'learning curve' effect.

Statement 7 *We would often be able to use the same subcontractor for the construction of the M&S plant.*

- This statement is based on condition 2 and 3 from Chapter 5; Procurement discounts and 'Learning curve' effect. The statement forces the respondent to choose his perception regarding the use of the same subcontractor. If the overall perception in the company is positive regarding the use of the same subcontractor for multiple M&S plants this is a positive thing for the M&S business model. Namely, using the same subcontractor will create more potential to obtain future discounts and will allows built up of the 'learning curve'.

Statement 8 *The M&S plant will definitely be built in a fabrication shop.*

- This statement is based on condition 5 from Chapter 5; Using a fabrication yard. The statement will give an indication of the overall perception of the respondents on the potential that a fabrication yard will be used for the M&S business model. A fabrication yard reduces schedule and safety risks. If the overall perception is positive this is a positive thing for the M&S business model.

Statement 9 *We would often be able to use our own fabrication yard for the construction of the M&S plant.*

- This statement is based on condition 6 from Chapter 5; Owning a fabrication yard. Owning a fabrication yard means that the plant engineer is able to store an inventory for his M&S plants. Therefore, in case that the overall perception of the respondents is positive for this statement this increases the chance of success for the M&S business model.

Statement 10 *There will be no difficulties in bringing forth the 'cultural change' for adopting the M&S business model and gaining enough company commitment.*

- This statement is based on condition 7 from Chapter 5; Company commitment. Company commitment, and the potential to gain it within the current company culture, is a very important element in the acceptance of a the new M&S business model. For this reason, a high level of agreement on this statement will increase the chance for the success of the M&S business model.

Statement 11 *Standardization will save the company substantial costs in the development of subsequent plants.*

- This statement is based on condition 1 from Chapter 7; Standardization. Standardization can of course entail major benefits for the M&S plant. Namely, it is argued that standardization can save substantial front end costs for subsequent M&S plants. This statement tries to tap the perceptions that the plant engineering company has on how great they deem the chance that they will save costs with standardization. A high level of agreement in this statement is a positive outcome for the M&S business model.

Statement 12 *Applying design variation in the M&S plant design will have a small impact on overall costs.*

- This statement is based on condition 2 from Chapter 7; Design variations. Applying design variations is a costly endeavor when using the M&S business model. For this reason, when most of the respondents agree with this statement this increases the chance of success for the M&S business model.

Statement 13 *Applying 'technological improvements' or 'design updates' will have a small impact on overall costs.*

- This statement is based on condition 3 from Chapter 7; Design variations. Technological improvements are, just like design variations, a costly endeavor when using the M&S business model. For this reason, when most respondents agree with this statement this increases the chance of success for the M&S business model.

Statement 14 *The resources required (time and money) to adjust to the customer/market segment for M&S plants are small.*

- This statement is based on condition 4 from Chapter 7; Market segment fit. A standard product from the M&S business model might attract a different market or customer segment then customized product from the 'traditional' business model. The development of this new market segment is a costly process. For this reason, when most respondents agree with this statement this increases the chance of success for the M&S business model.

Statement 15 *There is enough potential in the market to sell our relatively 'low capacity' M&S plants.*

- This statement is based on condition 5 from Chapter 7; Plant capacity. From this condition it became clear that there is much higher chance of success to sell M&S plants when they have a *relative* low capacity. Thus, when the respondents perception is that they will be able to sell these 'low capacity' (agree with this statement) M&S plants this increases the chance of success for the M&S business model.

Statement 16 *We can keep the module size small (small is container size).*

- This statement is based on condition 6 from Chapter 7; Module size. As mentioned in this condition, the smaller the module size the lower the costs and risks. For this reason, when the most of the respondents agree with this statement this increases the chance of success for the M&S business model.

Statement 17 *It is relatively easy to transfer, or interchange, generic individual modules between different plant designs.*

- This statement is based on condition 7 from Chapter 7; Modular transferability. Modular transferability refers to the potential to interchange individual modules (1) from previous (modular) plants to the new M&S plant or to (2) use certain individual modules from the 'new' M&S plant to future (standard and modular)plants. In case that most of the respondents agree with this statement this will increase the change of success for the M&S business model.

About the author

The author of this thesis was born in Voorburg, The Netherlands on 4th of April 1989. Secondary school education was completed in 2007 at the "Veurs Lyceum" where he obtained his High School diploma (HAVO). After his High School diploma the author obtained his Associate's degree in Process Technology (MBO4) at the "STC Brielle". Next, the author pursued and obtained a Bachelor degree in Chemical Engineering at the "Mainport University Rotterdam". Currently, the author is finalizing his Masters degree in Management of Technology at the "Delft University of Technology".

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